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Public Health Assessment for

FOCUSED
PETITIONED PUBLIC HEALTH ASSESSMENT
ISLA DE VIEQUES BOMBING RANGE
VIEQUES, PUERTO RICO
OCTOBER 16, 2001

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
Agency for Toxic Substances and Disease Registry

FOCUSED

PETITIONED PUBLIC HEALTH ASSESSMENT

Drinking Water Supplies and Groundwater Pathway Evaluation

ISLA DE VIEQUES BOMBING RANGE

VIEQUES, PUERTO RICO

Prepared by:

Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6)), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate.

In addition, this document has previously been provided to EPA and the affected states in an initial release, as required by CERCLA section 104 (i)(6)(H) for their information and review. The revised document was released for a 30-day public comment period. Subsequent to the public comment period, ATSDR addressed all public comments and revised or appended the document as appropriate. The public health assessment has now been reissued. This concludes the public health assessment process for this site, unless additional information is obtained by ATSDR which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

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FOREWORD

The Agency for Toxic Substances and Disease Registry, ATSDR, was established by Congress in 1980 under the Comprehensive Environmental Response, Compensation, and Liability Act, also known as the *Superfund* law. This law set up a fund to identify and clean up our country's hazardous waste sites. The Environmental Protection Agency, EPA, and the individual states regulate the investigation and clean up of the sites.

Since 1986, ATSDR has been required by law to conduct a public health assessment at each of the sites on the EPA National Priorities List. The aim of these evaluations is to find out if people are being exposed to hazardous substances and, if so, whether that exposure is harmful and should be stopped or reduced. If appropriate, ATSDR also conducts public health assessments when petitioned by concerned individuals. Public health assessments are carried out by environmental and health scientists from ATSDR and from the states with which ATSDR has cooperative agreements. The public health assessment program allows the scientists flexibility in the format or structure of their response to the public health issues at hazardous waste sites. For example, a public health assessment could be one document or it could be a compilation of several health consultations the structure may vary from site to site. Nevertheless, the public health assessment process is not considered complete until the public health issues at the site are addressed.

Exposure: As the first step in the evaluation, ATSDR scientists review environmental data to see how much contamination is at a site, where it is, and how people might come into contact with it. Generally, ATSDR does not collect its own environmental sampling data but reviews information provided by EPA, other government agencies, businesses, and the public. When there is not enough environmental information available, the report will indicate what further sampling data is needed.

Health Effects: If the review of the environmental data shows that people have or could come into contact with hazardous substances, ATSDR scientists evaluate whether or not these contacts may result in harmful effects. ATSDR recognizes that children, because of their play activities and their growing bodies, may be more vulnerable to these effects. As a policy, unless data are available to suggest otherwise, ATSDR considers children to be more sensitive and vulnerable to hazardous substances. Thus, the health impact to the children is considered first when evaluating the health threat to a community. The health impacts to other high risk groups within the community (such as the elderly, chronically ill, and people engaging in high risk practices) also receive special attention during the evaluation.

ATSDR uses existing scientific information, which can include the results of medical, toxicologic and epidemiologic studies and the data collected in disease registries, to determine the health effects that may result from exposures. The science of environmental health is still developing, and sometimes scientific information on the health effects of certain substances is not available. When this is so, the report will suggest what further public health actions are needed.

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2-A-DNT	2-amino-4,6-dinitrotoluene
4-A-DNT	4-amino-2,6-dinitrotoluene
ATSDR	Agency for Toxic Substances and Disease Registry
AFWTF	Atlantic Fleet Weapons Training Facility
DOH	Department of Health
DU	depleted uranium
EMA	Eastern Maneuver Area
EPA	U.S. Environmental Protection Agency
FDA	Food and Drug Administration
HMX	cyclotetramethylene tetranitramine
kg	kilogram
LIA	Live Impact Area
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
mg	milligram
MRL	minimal risk level
NASD	Naval Ammunitions Support Detachment
NRC	Nuclear Regulatory Commission
NRSC	Naval Radiation Safety Committee
OB/OD	open burning/open detonation
PCB	polychlorinated biphenyl
PHA	public health assessment
ppb	parts per billion
PRASA	Puerto Rico Aqueduct and Sewer Authority
PRDOH	Puerto Rico Department of Health
PREQB	Puerto Rico Environmental Quality Board
RDX	cyclotrimethylene trinitramine
RfD	reference dose
SMCL	secondary maximum contaminant level
SVOC	semi-volatile organic compound
TDS	total dissolved solids
tetryl	methyl-2,4,6-trinitrophenylnitramine
THM	trihalomethanes
TNT	2,4,6-trinitrotoluene
U.S.	United States
USGS	United States Geological Survey
UXO	unexploded ordnance
VOC	volatile organic compound

SUMMARY

Isla de Vieques (Vieques) is part of the Commonwealth of Puerto Rico, located about seven miles southeast of the main island of Puerto Rico. The United States Navy (Navy) owns approximately one-third of the island and conducts military training exercises that, until recently, included live bombing. Live bombing was conducted over an area of about 900 acres known as the Live Impact Area (LIA), located on the east side of Vieques to the west of the Punta Este Conservation Zone. Residents of Vieques live in the central portion of the island, where tourism, agriculture, and fishing dominate the economic market. The LIA is about 7.9 miles away from the residential population.

A resident of Vieques requested (petitioned) the Agency for Toxic Substances and Disease Registry (ATSDR) to determine if hazardous substances from the detonation of munitions at the Navy's bombing range pose a public health threat. A hazardous substance can affect human health only if people come into contact with the substance at the source or if the substance is transported to the public through a pathway (e.g., air, groundwater, soil, or biota). This public health assessment specifically focuses on the drinking water pathway with particular emphasis on explosive-related contamination. In the future, ATSDR will publish additional focused public health assessments that will address specific questions about the air, soil, and biota pathways as the data become available.

Historically, rainwater and groundwater have been used to supply the residents of Vieques with drinking water. Because of maintenance and salt water intrusion problems, the primary source of groundwater, the Esperanza valley well field, was shut down in 1978. In 1977, an underwater drinking water pipeline from the mainland was built. Most residents receive their drinking water supply from the Puerto Rico mainland through this pipeline. This water is stored in aboveground tanks prior to distribution. A few public and private groundwater wells still exist on the island and are occasionally used when the public water supply is interrupted. The number and current use of rainfall collection systems are unknown.

The United States Environmental Protection Agency (EPA), the Puerto Rico Department of Health (PRDOH), and an environmental firm hired by the Navy sampled public water supply tanks and groundwater wells on Vieques to characterize drinking water supplies. ATSDR also reviewed data collected by the Puerto Rico Environmental Quality Board (PREQB) and the U.S. Geological Survey (USGS) from monitoring wells (not used for drinking water supply) or other inactive or closed wells. After evaluating the findings of those investigations of groundwater and drinking-water sources and comparing detected levels of contamination to health-based guidelines known to be protective of public health, ATSDR determined that only nitrate plus nitrite levels in Well 3–7, a shallow, private drinking water well, were a public health hazard.

ATSDR concluded the following about the drinking water pathway:

The public water supply system is safe to drink. People who drink the water provided by Compania de Aguas from the mainland are not being exposed to harmful levels of contaminants.

Drinking the groundwater from the three Sun Bay wells, the four B wells, and Well 2–3 does not pose a public health hazard. The levels and types of chemicals detected are naturally occurring and are not expected to cause adverse health effects if or when these wells are used for drinking water supply when the public water supply is interrupted.

The concentration of nitrate plus nitrite, most likely resulting from agricultural pollution, in Well 3–7, a private drinking water well, was detected at levels higher than those that are considered safe for children. Because of elevated concentrations, ATSDR has determined that **a public health hazard** exists for people, especially children and pregnant women, who drink water from Well 3–7. PRDOH has issued an advisory and has personally informed the residents that water from this well is not safe for consumption.

At this time, ATSDR does not have any use or sampling data for the rainfall collection systems that are being used as a source of drinking water. ATSDR will revisit this potential pathway when new information or data become available on the occasional or continuous use of rainfall collection systems for the supply of drinking water.

Very low levels of explosives and potential products of explosive combustion were reported in drinking water data from 1978, however, the validity and utility of the data is uncertain. None of the data provided any evidence which would lead agency scientists to conclude that the water sampled posed a past public health hazard on the island. Even assuming the validity of the data and the presence of the compounds, the reported concentrations were well below levels considered harmful to human health.

I. INTRODUCTION

In May 1999, the Agency for Toxic Substances and Disease Registry (ATSDR) was requested (petitioned) by a resident of Isla de Vieques (Vieques), Puerto Rico to determine whether hazardous substances from the detonation of munitions at the United States Navy (Navy) bombing range on the island pose a public health threat. ATSDR conducted a site visit to Vieques in August 1999 to meet with the petitioner, tour the island and bombing range, and gather available environmental data. As a result of this site visit, ATSDR accepted the resident's petition and initiated a public health assessment (PHA) to investigate public health concerns related to operation of the Navy's bombing range on Vieques.

> A request from a concerned individual to evaluate a site is received through a written document known as a petition.

An ATSDR PHA includes a review of chemical releases from a facility or site and a determination of whether members of the public come into contact with these chemicals. If the review of the environmental data shows that people have or could come into contact with hazardous substances, ATSDR scientists then evaluate whether there will be any harmful effects from these exposures. This process may be lengthy, especially when addressing complex environmental issues. In order to be responsive to the resident petitioner and the people of Vieques, ATSDR will publish focused PHAs that will address specific questions as data become available. These PHAs are focused on specific pathways of potential human exposure to contaminants. Any exposures identified while developing the focused PHAs will be considered together to ensure the evaluation of the total exposure to a chemical, even if that exposure comes through several pathways.

This PHA defines the issues to be addressed on Vieques in this and subsequent focused PHAs. One of those issues defined in this PHA is the concern residents have expressed about how activities at the Live Impact Area (LIA) could affect the quality and safety of drinking water on Vieques. ATSDR realizes that other potential sources for contamination (e.g., local industries, car exhaust, municipal landfill, and farming/cattle ranching) exist on the island. However, these other sources are not discussed in this PHA unless they are determined to constitute a health concern. The focus of this report is to answer the petitioner's concern regarding potential contamination from the LIA.

Currently, water supplied to the residents of Vieques is piped in from the mainland of Puerto Rico. Water resources used by residents of Vieques in the past include groundwater wells and rainfall collection systems that are still used to a lesser extent today. This PHA fully addresses the current water supply and groundwater well usage. However, additional modeling and data collection are needed for the evaluation of the impact, if any, of Navy bombing operations on rainfall collection systems on the island. This information will be evaluated in a future PHA addressing the potential for chemicals to move through the air to the populated areas of Vieques.

Additionally, future work will also address the potential for chemicals to be incorporated into the food chain and be carried to the communities in the food they eat.

A very important aspect of the public health assessment process is to define and address health concerns of community members. Throughout the public health assessment process, ATSDR has been working and will continue to work with the community to define specific health issues of concern. On multiple trips to the island, ATSDR has met with a variety of individuals and organizations, including local officials, physicians, nurses, pharmacists, leaders of women's groups, school educators, fishermen, and businessmen. ATSDR also met with individual families who live on the island to understand their health concerns. Meeting with community members is critical to determine health issues of concern and to assess the environmental health issues on Vieques. Discussions with the community have also helped define ways in which ATSDR can provide information to the community on issues of health concern. Throughout the process, ATSDR will work with physicians, nurses, and school officials to provide educational materials that will benefit the communities and support the overall public health of residents of Vieques.

This document is a result of ATSDR's evaluation of drinking water and groundwater resources on Vieques. This information was presented for public comment in a draft dated February 20, 2001. This focused PHA on drinking water and groundwater addresses the comments received during the public comment period in Appendix F.

II. BACKGROUND

Vieques is approximately seven miles southeast of the main island of Puerto Rico (Figure 1). It is the largest offshore island that is part of the Commonwealth of Puerto Rico—20 miles long, 4.5 miles at its widest point, and about 33,088 acres in area (51 square miles). Vieques has low rounded hills and small valleys, with an east-west ridge near the center. The average elevation is about 246 feet above mean sea level. The highest point is Monte Pirata (987 feet above mean sea level), which is located in the southwest corner. There are no permanent streams (i.e., no surface water drinking supplies) on the island; however, after rainfall, temporary streams flow for a few days (Cherry and Ramos 1995).

Land Use:

Historically, sugarcane was grown throughout the island and milled in *Centrales* (Torres-Gonzalez 1989). The sugarcane industry caused a peak in Vieques' economic growth in the late 19^{th} century, however, sugarcane is no longer commercially grown on the island. The Navy bought much of the island in the 1940s, after the decline suffered by the sugar cane industry. The Navy used the eastern third and western third of Vieques until 2001, when the western third of the island was released to la Isla de Vieques, the Puerto Rico Conservation Trust, and the U.S. Department of the Interior. Manufacturing became more important for the economy in the 1960s and 1970s, especially with the construction of the General Electric Plant in 1969 (Bermudez 1998). Currently, there is minimal manufacturing on the island.

Currently, the land is used mostly for cattle pasture land, minor agriculture, and urban development. In the past, sugarcane was the principle crop on the island. Other crops have included coconut, grains, sweet potatoes, avocados, bananas, and papayas. Commercial fishing is operated out of both Esperanza and Isabel Segunda. More recently, tourism has been increasing in economic importance. Small restaurants and hotels have been opened in the cities.

Demographics:

ATSDR examines demographic information (i.e., population information) to identify the presence of sensitive populations, such as women of childbearing age (ages 15 to 44), young children (age 6 and under), and the elderly (age 65 and over). Demographics also provide details on residential history in a particular area—information that helps ATSDR assess time frames of potential human exposure to contaminants.

The 2000 U.S. Census Bureau reported that 9,106 people live on Vieques. This figure includes residents on both the residential lands and Navy property. Three potentially sensitive populations were identified: women of childbearing age, children, and the elderly. About 19% (1,701 residents) of the population consists of women of childbearing age. Children account for 11%

(1,001 residents) of the population and 14% (1,263 residents) of the population is elderly. According to several anecdotal accounts, the population of Vieques is not highly mobile; many are lifelong residents of the island.

Most of the residents of Vieques live in the two largest towns on the island, Isabel Segunda and Esperanza. Although these towns are located relatively close to the Navy property, they are several miles removed from the LIA. Specifically, the nearest point on residential lands to the geographic center of the LIA is approximately 7.9 miles (12.7 kilometers). Therefore, before any contaminants from the LIA can reach the residential populations of Vieques, they would have to travel over a distance of at least 7.9 miles.

Geology:

Vieques was formed from igneous and volcanic rock, mostly granodiorite, quartz diorite, and some lavas which created the bedrock of the island. This bedrock is exposed and weathered on most of the western half of the island and on the central portion of the eastern half of the island. Because of the weathering of the bedrock, gravel and sands wash downhill during storms. Over the years this material has gathered in valleys by the ocean, forming alluvial deposits (sediment deposited by flowing water) where the valley meets the sea. The alluvial sedimentary deposits generally consist of a mixture of gravel, sand, silt, and clay. Other portions of Vieques have ancient marine deposits from a time when the island was submerged, revealing areas with some limestone, sandstone, siltstone, and other sedimentary rocks at the surface.

Hydrogeology:

All the groundwater on Vieques is derived from rain that falls on the island. This water runs downhill as intermittent stream runoff or it seeps into the soil and underlying deposits. Water in pore space, cracks, and fractures in the weathered bedrock eventually flows to the ocean or into alluvial deposits.

There are two main types of aquifers on Vieques.

> An aquifer is an underground layer of earth, gravel, or porous rock that yields water.

The first type is within the upper portion of the bedrock and sedimentary rocks. The weathering, fracturing, and faulting of this rock has created pore space, joints, or fractures where water can seep underground. *The flow of groundwater in these unnamed aquifer systems is controlled by the influence of gravity and flows in a downhill direction* through the pore space and along fracture or joint surfaces. Although groundwater flow may be locally obstructed in areas where dense, nonporous rock or fault surfaces block the downhill flow, *the groundwater cannot flow through the bedrock in an east-west direction from one side of the island to another*. This fact was confirmed in a groundwater study that examined monitoring wells installed across the center of the island from north to south along the boundary of the Eastern Maneuver Area (EMA) [CH2MHILL and Baker 1999].

The second type of aquifer is within the alluvial deposits where water seeps into the sand and gravel areas, filling up the pore space between these materials. These alluvial aquifers are found below the hills in the low flat valleys along the coast (Figure 2). Water flow within these aquifers is also downhill and generally towards the sea in most cases. The alluvial aquifers are self-contained; *water cannot flow from one alluvial aquifer to another on the island.*

Within Esperanza valley, the largest alluvial valley in Vieques, is the primary aquifer on the island. The alluvial deposits extend from the vicinity of Ensenada Sombre in the residential area to Bahia Tapon in Camp Garcia. The United States Geological Survey (USGS) studied the Esperanza valley in 1989 and reported that groundwater flow in the alluvial deposits of Esperanza valley was toward the south and the sea. Other aquifers studied by USGS include: the Resolucion valley aquifer, the Playa Grande aquifer, and the Camp Garcia aquifer (Figure 2). Small unnamed alluvial deposits exist around the island, and they may contain groundwater, but they have not been used or studied.

Esperanza valley is located in the south-central area of the island. The area of the valley is about 10 square miles and the alluvial deposits are about 60 feet thick. The water table ranges from 10 to 100 feet above mean sea level. Transmissivity values (the rate of groundwater flow through a certain thickness) have been reported as ranging from 200 square feet (ft^2)/day near Camp Garcia to as much as 2,000 ft^2/day east of Ensenada Sombre. The hydraulic conductivity (the rate of groundwater flow) of the valley increases toward the coast where the amount of sand in the deposits increases. Hydraulic conductivity values for the valley have been estimated as less than 1 ft/day along the north-central hills in the valley to as much as 35 ft/day near the coast. Rainfall is the primary source of recharge to the aquifer; with the rainy season usually from August to November. Recharge is limited by the low permeability of limestone located along the south-central shoreline and by a 5-foot thick clay layer that exists near the top of the aquifer at a depth of 25 feet or less.

Within Resolucion valley is an 8-square mile aquifer located in the northwestern section of Vieques. The alluvial deposits average about 30 feet thick and overlie the bedrock (granodiorite and quartz diorite). This valley also has a semi-confining clay layer at about 20 to 30 feet below ground surface. Because of its location next to Monte Pirata, the highest point on the island, this aquifer typically receives more rainfall recharge than the others.

Climate:

Vieques climate is tropical-marine with temperatures that average about 79 degrees Fahrenheit. Annually, the temperature ranges from an average of 76 degrees Fahrenheit in February to 82 degrees Fahrenheit in August. Vieques lies in the path of the easterly trade winds, which regulate the rainfall on the island. The average amount of precipitation is about 45 inches a year. The western part of the island receives a higher amount of rainfall (about 50 inches a year) than the eastern section (about 25 inches a year). The rainy season is from August through November while the remainder of the year is drier. Tropical storms are common from June to November (NCDC 1985–1994; Torres-Gonzalez 1989).

In the summer, Vieques receives an increase of airborne dust particles through the natural occurrence of African dust storms. Each year, large quantities of dust from the Sahara Desert in Africa are transported at high altitudes to the Caribbean Sea and southeastern United States. The African dust can include soil fungus (e.g., *Aspergillus*), chemicals (e.g., iron, phosphorous, and sulfates), or even insects (e.g., African desert locusts) [USGS 2000].

Navy Operational History:

The Navy has occupied portions of Vieques since 1941, when 10,362 people lived on the island (Bermudez 1998). The Navy facilities are under the command of the Roosevelt Roads Naval Station on the mainland of Puerto Rico. In 1960, the Navy established targets on Vieques and, in 1971, began training exercises on the eastern part of the island. EMA is located to the east of the residential land and is used for training by Marine amphibious units, battalion landing teams, and combat engineering units. Camp Garcia is located within the southern section of EMA. Further east, the Atlantic Fleet Weapons Training Facility (AFWTF) is used for naval gunfire support and air-to-ground ordnance delivery training (CH2MHILL and Baker 1999). At the eastern end of the island, within AFWTF and to the west of the Punta Este Conservation Zone, is the LIA, where live bombing occurred. Recently, however, the Navy and the Commonwealth of Puerto Rico agreed that only nonexplosive bombs (including inert and practice bombs), instead of live munitions, would be used. Prior to May 2001, the Navy owned 8,200 acres on the western third of the island for the Naval Ammunition Support Detachment (NASD). Most of the NASD lands are undeveloped and were used for limited Navy operations, mainly storage. In May 2001, the Navy transferred most of the NASD to la Isla de Vieques, the Puerto Rico Conservation Trust, and the U.S. Department of the Interior. The Navy retained about 1% of the former NASD lands for a communication facility (Navy 2001a).

The LIA has, until 1999, been used for live ammunition training from off-shore ships, airplanes, and land-based personnel. The major exercises usually occur in the spring and fall with smaller activities conducted throughout the year (IT 2000). Within the LIA an Open Burning/Open Detonation (OB/OD) area is used to treat unexploded ordnance (UXO; i.e., bombs or explosive projectiles that did not explode) and to detonate waste military munitions. The UXO are taken to the authorized area and detonated with a remote control charge. If UXO cannot safely be transported to the OB/OD area, it is detonated on site in accordance with all existing requirements.

Many different types of military ordnance (e.g., fire bombs, parachute flares, rockets, inert rockets, machine guns, practice bombs, and live explosives) were used at Vieques. The explosive components of the bombs include 2,4,6-trinitrotoluene (TNT), cyclotrimethylene trinitramine (RDX), methyl-2,4,6-trinitrophenylnitramine (tetryl), cyclotetramethylene tetranitramine (HMX), ammonium picrate (explosive D), and various combinations of these chemicals. Two types of explosives were commonly used at Vieques. Each has a different set of byproducts from the explosion reaction.

> When a bomb explodes, a sphere forms of very hot gases that are at a high pressure. The hot gases expand very quickly causing fragmentation of the outer shell. The hot material then cools and stops expanding. At the end, a steady state is reached at a much lower temperature and pressure. All this occurs within one second from the time of the explosion (Young 1978).

> The first kind of explosive is made from organic nitrated compounds (i.e., only carbon, hydrogen, oxygen, and nitrogen). Carbon dioxide (35%), nitrogen (27%), and carbon monoxide (16%; which rapidly oxidizes to carbon dioxide) are the primary byproducts that result from an explosion from this type of bomb. Water (8%), ethane (5%), carbon (6%), and propane (2%) are other minor byproducts. Trace amounts (less than 1%) of ammonia, hydrogen, hydrogen cyanide, methane, methyl alcohol, and formaldehyde are also formed.
>
> The second kind of explosive contains aluminum. The byproducts from a bomb made with this type of material includes all the chemicals listed for the first kind as well as acetylene, ethylene, phosphine, and aluminum oxide. The primary byproducts are aluminum oxide (38%), carbon monoxide (24%; which rapidly oxidizes to carbon dioxide), nitrogen (18%), and carbon (13%). Ethane (3%), water (1%), and hydrogen (1%) are formed to a lesser degree. Less than 1% of the remaining byproducts (i.e., carbon dioxide, ammonia, propane, hydrogen cyanide, methane, methyl alcohol, formaldehyde, acetylene, ethylene, and phosphine) are formed (Young 1978).

Historically, during typical naval gunfire support training, 82% of the bombs used have been nonexplosive bombs and 18% were live bombs. During typical air to ground ordnance delivery training, 85% of the bombs used were nonexplosive bombs and 15% were live bombs (Navy 1990). Generally, bombing activities are the greatest in February and August with fewer maneuvers in April, May, November, and December.

A recent event that resulted in community concern was the inadvertent use of depleted uranium (DU) ammunition during a February 19, 1999 training exercise (NRC 2000). On that date two U.S. Marine Corps aircraft fired 263 rounds of ammunition armed with DU penetrator projectiles on the LIA. The use of DU ammunition rounds on the LIA is not authorized under the permit issued by the Nuclear Regulatory Commission (NRC). Navy personnel reported the incident to the Environmental Quality Board in person as soon as notification was received from the U.S. Marine Corps.

The NRC was notified by the Naval Radiation Safety Committee (NRSC) on March 5, 1999 and between March 10 and 19, 1999 a team of Navy health physics personnel were sent to the LIA. That team successfully recovered the equivalent of 57 complete DU penetrators. The Navy has committed to recover all detectable DU penetrators from the LIA and has reportedly as of September 2001, recovered 116 equivalent units. Removal of the remaining units will be accomplished during range refurbishment as the units are exposed over time. The remaining units are in locations where UXO is a concern. The NRC continues to monitor the Navy's efforts to recover the remaining DU rounds (NRC 2000).

From June 6 to 15, 2000 the NRC conducted an inspection of Vieques including the LIA, the EMA, the central residential sector of the island, and the NASD area. That inspection was for the purpose of collecting direct radiation measurements and environmental samples, for subsequent analysis, to evaluate if the DU rounds fired by aircraft on the LIA may have contaminated the environment and, in turn, may result in a potential source of radiation exposure for Vieques residents. Sampling locations were selected based upon a predetermined grid. A total of 84 soil, 17 vegetation, seven surface water, and six sediment samples were collected.

The results of the NRC investigation were released on September 28, 2000 and disclose that the only detections of uranium, at levels above the natural background level, were measured in five samples collected in the holes where DU rounds were found. The NRC concluded that there was no spread of DU to areas outside the LIA and that the public outside the LIA has not been exposed to DU contamination or radiation above normal background levels (NRC 2000). Further, the NRC concluded that Vieques inhabitants could have only received a measurable dose of radiation from the DU firing event if they had direct access to a DU penetrator for an extended period of time (NRC 2000).

ATSDR has reviewed the findings of the NRC report and concludes that the levels of radiation detected on Vieques do not represent a public health hazard. This DU ammunition firing event does not represent a potential source of groundwater or drinking water contamination. For this reason, this potential source of contamination will not be discussed further in this PHA.

Quality Assurance and Quality Control:

In preparing this PHA, ATSDR reviewed and evaluated information provided in the referenced documents. The environmental data presented in this PHA are from reports produced by the Navy, Puerto Rico Department of Health (DOH), USGS, NRC, and the United States Environmental Protection Agency (EPA). The limitations of these data have been identified in the associated reports. The sampling procedures, analytical methods, and detection limits established for those investigations were consistent with the objectives of those investigations. Based on our evaluation, ATSDR determined that the quality of environmental data available in the site-related documents for Vieques is adequate to make public health decisions.

III. PATHWAY ANALYSIS

This section of the PHA addresses the potential for human exposure to contamination. Figure 3 describes ATSDR's exposure evaluation process. ATSDR identifies and evaluates exposure pathways by considering how people might come into contact with, or be exposed to, a contaminant. For a public health hazard to exist people must come into contact with areas of potential contamination, contamination must be present, and the amount of contamination must be sufficient to affect people's health.

> There are five elements in an exposure pathway: source of contamination, environmental media, point of exposure, route of human exposure, and receptor population. The source of contamination is the place where the contaminant was released. The environmental media (i.e., groundwater, soil, surface water, air, etc.) transports the contaminant. The point of exposure is the location where humans come in contact with the contaminated media. The route of exposure (i.e., ingestion, inhalation, dermal contact, etc.) is how the contaminant enters the body. The persons actually exposed are the receptor population. ATSDR considers these elements in the past, present, and future.

For the purpose of evaluating the public health impact of chemical releases into the environment, it is critical to determine if any people come into contact with the chemicals. If no one comes into contact with a chemical, then there is no exposure; therefore, no health effects could occur. Often the general public does not have access to the source area of the environmental release; this lack of access makes it more important to determine whether the chemicals are moving through the environment to where people may come into contact with them. The route of movement of chemicals is the *pathway*. An exposure pathway may involve air, surface water, groundwater, soil, dust, or even plants and animals.

Completed Pathways:

A *completed pathway* exists when the five elements of a pathway connect a source of contamination to a receptor population. If contaminants migrate from a source area to a point where people can contact them, a completed pathway of exposure could exist. In addition, completed pathways are likely to occur when people enter source areas. For example, anyone entering the LIA or the OB/OD area could potentially come into contact with chemical residue from the detonation of explosives in soil and water at the site. Additionally, there is a risk of disturbing UXO and detonating it, with obvious related health effects.

Navy personnel or their contractors routinely spend no more than eight to ten weeks per year cleaning the LIA's targets during the semi-annual refurbishment efforts. Therefore, the population potentially exposed for the greatest length of time were the protestors who occupied the LIA from April 1999 until May 2000. Soil samples are needed from these areas in order to permit exact definition of which chemicals are in the soil, so that a health evaluation can be completed.

At the request of ATSDR, the Navy collected surface samples on the LIA and recorded sample locations. Evaluation of these samples will be addressed in a future PHA.

Potential Pathways:

A *potential pathway* exists when information for one of the five elements is unknown or missing. There are several potential pathways that may exist on Vieques. For example, if the wind carries potential contaminants 7.9 miles from the LIA to the residential section of Vieques, people could be potentially exposed through the air, through dust as it settles, or through the food chain. In addition, contaminated soils may be washed into the sea from the LIA. People could be potentially exposed if those contaminants migrated to populated areas or entered the food chain.

Data do not yet exist to permit direct assessment of these potential pathways. ATSDR will continue to work with other agencies to collect relevant data and, where necessary, to model the movement of chemicals in the environment.

This PHA, Drinking Water Supplies and Groundwater Pathway Evaluation, evaluates only those pathways that potentially impact drinking water supplies on the island. Other pathways are not assessed in this PHA, but will be addressed by ATSDR in the future as more data become available and the public health implications of the data are assessed. The pathways evaluated in this PHA are summarized in Table 1. The following questions regarding the safety of the drinking water supplies on Vieques are addressed in this PHA:

1. Is the current public water supply safe to drink?

2. Is the groundwater on Vieques safe to drink?

3. Is the water from rainfall collection systems safe to drink?

Future PHAs will address the remaining issues related to completed or potential pathways from the LIA to the residents of Vieques. The issues being evaluated by ATSDR at this time include:

1. The potential for contaminants to travel from the LIA to populated areas of the island through the air will be addressed in a future focused PHA. It will address potential exposures through the air, including the impact of any air transport of chemicals on dust, soil, and water. A further discussion of rainfall collection systems will also be included.

2. The potential for contaminants to travel from the LIA and deposit in residential areas of Vieques will be addressed in a focused PHA concerning exposures to soil on Vieques. This document will address exposures that the residential population

might typically experience as well as exposures that individuals who lived on the LIA between April 1999 and May 2000 might have experienced.

3. The potential for residents to be exposed to contaminants through consumption of fish and shellfish collected in the nearby waters will be addressed in a future focused PHA.

As ATSDR's investigations proceed, additional issues and concerns may be identified and, if so, they will be evaluated.

The Groundwater Pathway:

The petitioner and other residents of Vieques have voiced a concern that contaminated groundwater may move from beneath the LIA and the OB/OD area to the populated areas of Vieques. *However, the geology and topography of the island prevents groundwater from moving in that direction.*

Groundwater from the LIA does not flow west into the residential area of Vieques.

Any groundwater that might exist in the marine sediments and sand deposits at the LIA and the OB/OD area will move slowly downhill, under the influence of gravity, toward lagoons and the ocean that surround the LIA on most sides. Any movement of groundwater westward would be intercepted by the sea and lagoons on either side of the isthmus, or else would be prevented from further migration by the rising bedrock and topography of the island, west of the isthmus. *Therefore, groundwater cannot move uphill from the LIA westward—there is no connection between groundwater at the LIA and groundwater of the central portion of the island.* Neither the Esperanza aquifer, nor the shallow groundwater around Isabel Segunda and other populated areas of the island is directly impacted by groundwater beneath the LIA or the OB/OD area.

The only way the Esperanza aquifer or other groundwater in the center of the island could be impacted by operations at the LIA and the OB/OD area is through air transport, deposition, and later movement of contaminants through the soil into the underground aquifers. ATSDR does not know yet if any measurable amount of chemical residue has traveled through the air to these areas. However, recent groundwater sampling did not detect explosives or their residues in any groundwater on the island. Since the point of exposure, usable water, has been sampled and no ordnance-related contaminants found, the groundwater route is an incomplete pathway.

IV. EVALUATION OF THE DRINKING WATER QUALITY

Drinking Water Supplies:

The public water system on the island of Vieques is currently supplied with water from the main island of Puerto Rico. Any residents or businesses purchasing water from Compania de Aguas are getting water that was collected and treated on the main island of Puerto Rico, then piped into the distribution system through an underwater pipeline. This water originates in the mountains of the main island of Puerto Rico and is not affected by activities at the bombing range on Vieques.

> Most of the residents of Vieques currently receive their drinking water supply from the mainland of Puerto Rico through an underwater pipeline.

Prior to having water piped from Puerto Rico in 1978, the water distribution system on Vieques was supplied from groundwater wells on the island of Vieques. These wells, located in the Esperanza and Resolucion valleys, are within localized aquifers and are not connected to the groundwater on the eastern end of the island. Increasing water demands of the communities on Vieques and the increased salinity of these water supplies (because of salt water intrusion) mandated the need for a better water supply for residents of Vieques. The use of these wells was therefore, phased out when the decision was made to supply water from the main island of Puerto Rico by pipeline.

Prior to the existence of the current public water distribution system and the installation of the Esperanza and Sun Bay well fields in the early 1960s, water was supplied by smaller private groundwater wells and by rainfall collection systems. Some of these sources may still be used today to augment water supplies in some households and businesses.

Each source of water is addressed below in the form of answers to questions. The answers given are based on the most current epidemiologic, toxicologic, and medical information available. When available, chemical analysis of the water is evaluated to determine whether there is any indication that the water has been impacted by range activities and whether the water is safe to drink and use in the home. The current public water supply and various groundwater wells have been sampled and analyzed by PRDOH, USGS, an environmental firm hired by the Navy, and EPA. Sampling summaries are provided in Appendix B and a complete list of chemicals tested by each agency is shown in Appendix C. Earlier sources of water use are more difficult to address, particularly when limited chemical analysis is available or when there is uncertainty about where the samples were taken. At this time, data do not exist to permit a full evaluation of the use of rainwater collection systems on the island; this water source will be more fully addressed through additional environmental sampling on Vieques and through computer modeling of air dispersion to evaluate the potential for airborne contaminants to affect these systems.

Question 1: Is the current public water supply safe to drink?

Answer:

The water supplied by pipeline to the island of Vieques is safe to drink and is suitable for all home and business use.

Recent chemical analysis of water in the public water supply system indicates that the water has not been impacted by bombing activities at the LIA.

There is no completed pathway between the LIA and the OB/OD area and the public water supply system for the island of Vieques.

Discussion:

Drinking Water Supply:

Most of the residents of Vieques receive their drinking water supply from the mainland of Puerto Rico. An underwater pipeline was built in 1977 from the mainland to Vieques and provides 800,000 gallons of drinking water per day to the residents of Vieques (Cherry and Ramos 1995). The source of water is the Rio Blanco (i.e., White River), which originates in the Yunque Rainforest in the mountains of the main island of Puerto Rico. Compania de Aguas, a company hired by the Puerto Rico Aqueduct and Sewer Authority (PRASA) to maintain and operate the water supply system, is responsible for distributing drinking water to the residents of Vieques. Treated water from the Rio Blanco Filtration Plant in Naguabo, Puerto Rico, is distributed to the Arcadia storage tank in the NASD area on Vieques through the underwater pipeline. This above ground storage tank has an engineered cover and is not susceptible to atmospheric deposition. The water is further treated by chlorination just before it reaches the Arcadia storage tank. Drinking water from the Arcadia storage tank is then supplied to all the other distribution and storage tanks on the island, which in turn supply water to both residents and Navy personnel. Figure 4 graphically displays the locations of the tanks in the public water supply system.

Sampling Summary:

The water provided from the mainland was sampled for many different types of chemicals, including explosives, metals, other inorganics compounds, herbicides, pesticides, polychlorinated biphenyls (PCBs), volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and radionuclides. Various tanks and taps within the PRASA public water supply system on Vieques were sampled by EPA and by the Puerto Rico DOH at different times in 1999 and 2000 (See Appendix B for a summary). All public storage tanks and a tap that is representative of the public drinking water supply on the island were included in the studies.

Water from the Rio Blanco Filtration Plant in Puerto Rico, which provides the water piped to Vieques, was sampled for explosives by EPA. Additionally, in September 1999, an environmental consulting firm working for the Navy sampled the storage tank maintained by the Navy (NASD tank), splitting samples with EPA to confirm the findings. A sampling summary is provided in Appendix B and a complete list of chemicals tested by each agency is shown in Appendix C.

Water Quality:

Explosive-related chemical compounds were not detected in any of the samples, using current EPA approved analytical techniques. As disclosed in Table 2, the water from the public water supply system includes the usual, naturally occurring assemblage of metals and inorganic constituents and a few VOCs that are byproducts of water chlorination. Table 2 indicates the chemicals that were found and how much was present.

Evaluation of the Impact of Water Quality on Public Health:

The metals and other inorganic constituents found in the water from the public supply system reflect the geologic rock types, weathering, and soil formation occurring in the Rio Blanco watershed on the mainland of Puerto Rico. All these metals were present at concentrations well below any level of health concern. Barium, fluoride, aluminum, iron, manganese, and zinc were below the appropriate EPA drinking water standards (see Table 2). Additionally, the other inorganic compounds—chloride, sulfate, nitrate, and nitrite—were well within the applicable water standards. Although ammonia, boron, and strontium do not have maximum contaminant levels (MCLs, see text box for definition), the levels found in the Vieques drinking water are not a health concern. The small amounts one would be expected to ingest from the water is well below recommended maximum doses of these chemicals according to ATSDR's comparison with the minimal risk levels (MRLs) and EPA's reference doses (RfDs). Please refer to Appendix D for further details concerning how ATSDR estimated exposure doses and determined health effects.

> The maximum contaminant level (MCL) is the standard set by EPA for drinking water within public water supply systems. EPA considers the protection of human health when setting the MCL.

The remaining metals do not have EPA or ATSDR standards for comparison. However, the levels detected for the remaining metals are also very low. A person drinking this water every day would consume a very small amount of each of these metals. For example, the essential nutrients, magnesium and potassium, do not have EPA MCLs. In fact, the U.S. Food and Drug Administration (FDA) recommends people consume a minimum amount of these metals to stay healthy—400 milligrams (mg) per day for magnesium and 3,500 mg per day for potassium. Based on magnesium and potassium detected in the drinking water, Vieques adults drinking 3 liters of the water per day would consume 11.1 mg of magnesium and 3.9 mg of potassium—5.5 mg and

2.0 mg, respectively, for children drinking 1.5 liters per day. These amounts are far below the recommended intake of these essential nutrients and are in no way harmful to adults or children. In fact, the presence of these metals in the drinking water aids in supplying the body with two essential nutrients, although the contribution to the diet is very low.

All of the VOCs found in the water were also below their corresponding MCLs. ATSDR estimated exposure doses for VOCs by using the highest detected concentrations and assuming people drank 3 liters of water a day (1.5 liters for children) for 70 years (6 years for children). The resulting doses for both children and adults were orders of magnitude lower than levels believed to cause adverse health effects.

> An important step in ensuring that the water is safe to drink is disinfection. The public water supply system is treated with chlorine (a disinfectant) to kill any potentially existing microorganisms that can cause disease. Chlorine reacts with organic material that is naturally present in the water and forms disinfection byproducts.

The trihalomethanes (THM) found in the drinking water—including total THM, chlorodibromomethane, chloroform, and dichlorobromomethane—are known byproducts of drinking water disinfection and are most likely disinfection byproducts from the chlorination process rather than environmental contaminants. According to ATSDR dose calculations, the levels detected in the public water supply system for Vieques were far lower than levels known to cause adverse health effects. The presence of these compounds in the water at these low levels does not appreciably increase the risk of cancer or other adverse health effects.

Question 2: Is the groundwater on Vieques safe to drink?

Answer:

Water from the public supply wells in the Esperanza aquifer is safe to drink, according to all available analyses. The high total dissolved solids (TDS) and salinity may impact taste but are not a health hazard. When drinking from these wells, however, residents need to be aware of their additional sodium intake. Although the supply wells were not sampled for explosives, samples from other Esperanza aquifer wells are not contaminated by explosives.

There are no health hazards from exposure to explosives or their byproducts by drinking groundwater on Vieques. Although it was not possible to test the Esperanza drinking water supply wells for explosives, testing for explosives in other wells in that aquifer that are located closer to the LIA did not disclose the presence of those compounds. In addition, no other wells on the island detected the presence of explosives.

The water from Well 3–7, a shallow, private drinking water well, is **not** safe to drink because of elevated nitrate plus nitrite levels. Children, especially infants, and pregnant women should not drink water from this well. PRDOH has issued a health advisory on this well and notified local users. The levels of nitrate plus nitrite most likely result from agricultural pollution and are not conclusive evidence of explosive contamination.

Discussion:

Groundwater Resources for Drinking Water:

The fresh water supply on Vieques is limited by annual rainfall and the water stored in the alluvial aquifers. Prior to piping drinking water from the main island of Puerto Rico, the public water distribution system was supplied by pumping groundwater from wells in the Esperanza aquifer. Navy wells in the Camp Garcia area pump from connected alluvial deposits (Torres-Gonzalez 1989), which for the purposes of this report are considered the same alluvial system. Minor usage of the remaining aquifers on Vieques includes two Navy supply wells and approximately 14 individually owned wells across the center of the island, many of which were dry or unused when surveyed by the USGS in 1991 (Cherry and Ramos 1995). Figure 5 graphically displays the locations of the groundwater wells discussed in this PHA.

<u>Water Use of the Esperanza Aquifer:</u>

Several wells that pump from the Esperanza aquifer, including the Sun Bay and the B wells, were installed in the 1960s. PRASA operated these wells in the valley to provide drinking water for the residents of Vieques. During operation, the well field yielded an average of 425,000 gallons of water per day. Increased water production caused saline water to intrude into the wells near the coast. Chloride concentration, as a measure of salination, was shown to increase from around 100 mg per liter to as high as 300 mg per liter from 1973 to 1977 (Torres-Gonzalez 1989). This increase in salinity, as well as the natural limitation on the volume of water that could be pumped from the aquifer, were key factors in the decision to shut down the Esperanza valley well field in 1978.

Since groundwater management was initiated by PRASA in 1977, the Esperanza aquifer has nearly recovered to pre-developed conditions (CH2MHILL and Baker 1999). If properly maintained and utilized, the Esperanza valley well field could provide an alternate water source in the case of an emergency (Cherry and Ramos 1995). A two-dimensional groundwater model developed by USGS indicates that the aquifer can yield approximately 300,000 gallons of water per day during the wet season and 200,000 gallons per day during the dry season.

Until recently, Compania de Aguas maintained three Sun Bay wells that were used during emergencies (e.g., hurricanes, drought, or electrical outage) when the water supply from the mainland was interrupted. These wells are located in the Esperanza valley aquifer and are now reportedly closed. In the case of an emergency, the Sun Bay wells could be safely utilized, at least for a limited period of time. Four other wells, the B wells, are still available for emergency use.

In the past, the Navy also used groundwater wells in the eastern portion of this alluvial aquifer for its drinking water supply. Until 1998, Camp Garcia personnel received their drinking water from U.S. Marine Well 6 and Navy Well 14. Together, these two wells pumped 84,000 gallons of water per day, twice a week. However, in 1998, because of deterioration and maintenance problems, the Navy decided to bring drinking water from the NASD tank by tanker truck to Camp Garcia rather than continue to pump from these two wells. Navy Well 14 is now used to supply water to cattle.

Water Use of Other Alluvial Valleys:

Several former Navy wells were identified by USGS within the NASD in the Resolucion valley, along the northwest coast of the island (USGS 1997). Their former use is unclear for all but one of the wells—Navy Well 17 is known to be a former supply well (Cherry and Ramos 1995). None of the wells are currently usable.

A small unnamed alluvial valley north of Ensenada Honda also has one known well. A small (13 feet deep) hand-dug well was reportedly used by the Navy in this remote portion of the island. This well is apparently no longer in use, since it had chloride concentrations of over 4,000 mg per liter (Cherry and Ramos 1995).

Water Use of Other Groundwater Resources on Vieques:

The balance of the wells across the center of the island draw water from the upper portion of the weathered bedrock, from isolated patches of alluvial deposits, or from channels and faults in sedimentary rocks (e.g., limestone). Groundwater use is limited on Vieques because only minor aquifer recharge occurs from precipitation due to the high evapotranspiration rate (estimates suggest about 90% of the precipitation is lost to evapotranspiration, Torres-Gonzalez 1989).

Private wells outside of the Esperanza aquifer currently in use:

Well No.	Use	Depth (ft)	Chloride (mg/l)
10–2	D	14	156
2–2	Ag	—	—
2–3	E	17	108
3–4	D	—	176
3–5	D	14	240
3–7	E	9	90

D=Drinking water Ag= Agriculture E=Emergency Use
Cherry and Ramos 1995

Six wells were reportedly still in use in 1991 (Cherry and Ramos 1995). One well is used agriculturally to water livestock and three wells are used for drinking water and other domestic purposes. The last two wells (Well 2–3 and Well 3–7) are only used as an emergency water supply when the pipeline is not in operation. Well 2–3 is located in a remote area of the island, with access restricted by 80 to 100 feet of dense vegetation. Well 3–7 is located in a residential area where people fill containers with water from the well and take them home (EPA 1999b).

Sampling Summary:

In May 1995, PRDOH sampled the three Sun Bay wells and the four abandoned B wells on Vieques for VOCs, SVOCs, inorganics, metals, herbicides, pesticides, and PCBs. The USGS sampled five former Navy wells on NASD in November 1996 for inorganics. Three of these wells were additionally tested for VOCs and organochlorine pesticides. In August 1999, an environmental consulting firm hired by the Navy sampled the former supply well (Navy Well 17) on NASD property and the former drinking water well (Navy Well 14) in Camp Garcia for VOCs, SVOCs, inorganics, metals, herbicides, pesticides, PCBs, and explosives. In September 1999, EPA sampled the three Sun Bay wells and two emergency drinking water wells (Well 2–3 and Well 3–7) for VOCs, SVOCs, inorganics, metals, and explosives. Based on a review of the data, EPA determined that the explosives data were unusable; therefore, in January 2000, EPA returned and re-sampled the two emergency water wells for explosives and nitrate plus nitrite. The three Sun Bay wells were not re-sampled because they had been closed. See Appendix B for a summary of sampling by each agency and Appendix C for a complete list of chemicals tested by each agency.

Additional sampling was performed on monitoring wells. Monitoring wells are not used to supply drinking water to the public; rather, they are used to sample water quality in the aquifer. Because these wells are not used as a water source, the results at these wells are described only to help characterize the groundwater quality. In August 1999, the environmental consulting firm hired by the Navy installed 11 monitoring wells along EMA's western boundary and sampled them for explosives. Of the 11 monitoring wells installed along EMA's western boundary, two were placed to allow sampling in the alluvial deposits in the Esperanza aquifer. The remaining wells sample water within the weathered bedrock across the center of the island.

Water Quality:

Water Quality of the Esperanza Aquifer:

Water samples from the Esperanza aquifer contained metals, high levels of total dissolved solids (TDS), and high salt (sodium and chloride) [Table 3]. These results are consistent with earlier reports of high salinity in the Esperanza valley wells (Torres-Gonzalez 1989). In general, this aquifer is not a high quality water supply. Several of the metals found in the Sun Bay wells and the TDS in all wells are above their

> The secondary MCL (SMCL) is established based on secondary considerations such as taste, odor, and appearance, when health concerns are not an issue.

secondary maximum contaminant levels (SMCLs, see text box for definition). TDS—including boron, iron, manganese, and sodium—are commonly found in groundwater. The presence of these metals is directly related to the high levels of TDS in the water and probably reflects the natural geology of the island. Igneous and volcanic rocks, which make up the bedrock of Vieques, are a common source of iron and manganese (USGS 1997). Very small amounts of chloroform and total trihalomethanes were found in one of the B wells and in Navy Well 14. Di-n-butylphthalate was also detected in Navy Well 14.

Neither the Sun Bay wells nor the B wells were sampled for explosives by any agency. Currently, the Sun Bay wells are closed and there are no plans to reopen those wells; leaving them unavailable for re-sampling. Therefore, the only groundwater samples in the Esperanza aquifer available to characterize the potential for explosives contamination are the Navy wells that were sampled in 1999. Navy Well 14 was sampled for 16 explosive compounds and none were detected above the method detection limits (Table 3) [Baker 1999]. The Navy has also installed and sampled two monitoring wells in the alluvial deposits at EMA's western boundary (Well NW-8 and Well RCRA-4). As was the case with the old supply well, water samples from these wells did not contain any of the explosive compounds tested. All three of the Navy wells are located closer to the LIA than the Sun Bay wells and B wells and would detect any potential groundwater contamination from the LIA before it reached the Sun Bay wells and B wells.

Water Quality of Other Alluvial Valleys:

The Resolucion valley is the only other alluvial valley sampled. Navy Well 17 and four other former Navy wells in NASD were sampled by the Navy and USGS for the presence of contaminants. As was the case with water samples from the Esperanza aquifer, the Resolucion water samples had high TDS and salinity (sodium and chloride) with some trace metals (e.g., barium, calcium, and iron) [Table 4]. No explosives were detected above the method detection limits. Traces of benzene, chloroform, toluene, di-n-butylphthalate, and siloxane were found at levels very close to the method detection limits.

Water Quality of Other Groundwater Resources on Vieques:

Two of the six shallow water wells potentially in use by the general public were sampled by EPA—Well 2–3 and Well 3–7. In addition to expected trace metals (barium, boron, manganese, and zinc), these two wells had high TDS and a slightly higher salinity (chloride and sodium) than what was found in the Esperanza aquifer (Table 5). TDS does exceed the SMCL and chloride is close to the SMCL. The combined nitrate plus nitrite for Well 2–3 was similar to that of the Sun Bay wells, but Well 3–7 contained much higher levels, up to 12,600 parts per billion (ppb). This combined nitrate plus nitrite exceeds the MCL of 10,000 ppb. When EPA re-sampled Well 3–7, the nitrate plus nitrite levels were found to be considerably lower (1,700 ppb). However, after reviewing quality control data, EPA determined that the second sampling event probably underestimated the concentrations of those samples.

Di(2-ethylhexyl)phthalate (22 ppb in Well 3–7) was the only organic compound found in these wells. Although it was not detected in the laboratory quality control samples, EPA's laboratory noted that di(2-ethylhexyl)phthalate is a common laboratory contaminant and that the presence of di(2-ethylhexyl)phthalate is "most likely due to contamination of the sample during the collection and analysis of the samples" (EPA 1999b). Di(2-ethylhexyl)phthalate is a plasticiser in many common materials found both in the home and in the laboratory. Unless the well is known to contain synthetic materials that may contain di(2-ethylhexyl)phthalate, this result should be considered introduced by the laboratory.

Evaluation of the Impact of Water Quality on Public Health:

Explosives:

Currently, there are no health hazards from exposure to explosives or their byproducts by drinking groundwater on Vieques. No explosives were found in any of the groundwater wells tested (Baker 1999; CH2MHILL and Baker 1999; EPA 2000). Although it is theoretically possible that traces of explosives were present at levels below the limits of detection, no health effects would be expected at such low levels. The explosives reportedly used on the LIA include TNT, RDX, tetryl, HMX, and ammonium picrate (Navy 1990).

> The limit of detection is the lowest amount of a chemical that can be measured above the noise of the equipment.

The limits of detection for TNT, RDX, tetryl, HMX, and TNT degradation products are well below any level of concern for noncancer health effects, an indication that these adverse health effects would not be expected even if contaminants were present below detection limits. Additionally, dose calculations for water intake over a lifetime exposure, at the detection limits indicate that these levels of intake are below levels of concern for cancer health effects. The potential cancer effects of RDX, TNT, and dinitrotoluenes (TNT breakdown products) can be more thoroughly evaluated than HMX or tetryl because more is known about those compounds. Please refer to Appendix D for further details concerning how ATSDR estimated exposure doses and determined health effects.

Very low levels of RDX, tetryl, ammonia, and nitrate plus nitrite may have been present in drinking water samples taken by the Navy in 1978. The validity and utility of the data is uncertain because of the small number of samples collected and the description of the location or media represented by the samples. Regardless, the concentrations of explosive compounds reported in drinking water in the past were well below levels considered harmful to human health and any potential past exposure to these compounds would not have posed a public health hazard. Please refer to Appendix E for a discussion and evaluation of this sampling event.

Nitrate / Nitrite:

Nitrate plus nitrite (measured together as nitrogen) was elevated in Well 3–7 at 12,600 ppb. This well was not sampled for nitrate and nitrite separately; the nitrogen found could be from either nitrate, nitrite, or both. The detected level of nitrogen is above the MCL for either nitrate, nitrite, or both together (10,000 ppb, 1,000 ppb, or 10,000 ppb, respectively). Excessive levels of nitrate/nitrite in drinking water can cause serious short- and long-term health effects for children because nitrite interferes with oxygen uptake in blood (EPA 1995). The greatest concern is for infants or pregnant women who may be drinking water with elevated levels of nitrate or nitrite. Nitrate can be converted in an infant's intestines to nitrite. The nitrite can then interfere with the oxygen-carrying capacity of the child's blood. Older children and adults do not convert as much nitrate into nitrite, and therefore, nitrate is of less concern if older children and adults are exposed. Nitrite, on the other hand, is of equal concern for all ages, since it does not need to be transformed in the intestines to actively interfere with oxygen uptake in the blood.

Both adults and children drinking all their water each day from Well 3–7 would consume more nitrite than recommended each day, assuming that all of the nitrogen in the water represented nitrite. However, it is unlikely that all the nitrogen is attributable to nitrite because (1) the elevated nitrate/nitrite levels in this well are most likely a product of agricultural chemicals, which contain nitrate, not nitrite and (2) of the eight wells on the island that were sampled for nitrite, nitrite was never detected, and there is therefore, no indication that large amounts of nitrite would be expected in this well. If all the nitrogen was an indication of the presence of nitrate, there would be no hazard for adults and older children. However, infants might be at risk, especially if they are drinking formula made with this water. Finally, the two samples taken at this well had very different levels of nitrogen—12,600 ppb and 1,700 ppb. If the levels in the well are fluctuating seasonally or because of other factors, an increase in the nitrates in the well could pose a hazard for older children and pregnant women. Therefore, the levels of nitrite/nitrate in this well may pose a public health hazard. Children, especially infants, and pregnant women should avoid drinking this water. PRDOH has issued an advisory and has personally informed the residents that water from Well 3–7 is not safe for consumption.

Other Inorganics:

All the groundwater sources sampled have high levels of TDS, high salinity (sodium and chloride), and elevated levels of naturally occurring metals. Iron and manganese found in the Sun Bay and NASD wells and the TDS in all groundwater wells are above EPA's SMCL. Levels detected above the SMCL may affect the taste, odor, or color of the water or result in secondary health effects, such as discoloration of teeth. Chemicals found at levels above the SMCL do not indicate a health hazard; several of these elements are actually essential nutrients for the body. Although the supply wells in the Esperanza aquifer were used for less than 20 years, the discussion will assume a lifetime use in order to be protective of any individuals who may still be using groundwater as the primary source of drinking water in their home. Please refer to Appendix D for further details concerning how ATSDR estimated exposure doses and determined health effects.

The detected concentrations of TDS are well within levels EPA would consider to be usable (EPA considers water with more than 10,000,000 ppb of TDS to be unusable for drinking). In fact, some people may tolerate and/or actually enjoy the taste of water with high levels of TDS, especially if that is what they are used to drinking (EPA 1984). Included among the TDS are iron, manganese, sodium, and boron.

Iron, manganese, and sodium are important minerals that maintain basic life functions.

> Iron is used by the body to make hemoglobin, which transports oxygen in the blood from the lungs to other areas of the body that need oxygen. It also helps increase the body's resistance to stress and disease (ANR 2000). FDA's Daily Value for iron is 18 mg. ATSDR's calculated daily intake of iron from the Sun Bay wells was about one third of the Daily Value for adults and less than one fifth of the Daily Value for children. Iron was not detected in the other drinking water wells. The additional iron that would be received by drinking water from the Sun Bay wells is not harmful. The reason that an SMCL is set for iron is not that the iron can cause adverse health effects, but rather that water with high levels of iron may have an unpleasant taste to some people and may stain material that is washed in water with high iron concentrations.
>
> **The Daily Value is a reference point set by the FDA to help people understand what their overall dietary needs should be.**
>
> Manganese is an antioxidant that helps produce energy for the body. The average amount of manganese in a normal diet is about 1 to 5 mg a day (ATSDR 1997). However, very high levels of manganese in the diet may cause harmful effects. Therefore, ATSDR conservatively compared probable intake levels (i.e., ATSDR calculated doses) of manganese to available health guidance values and found that the detected concentrations were below levels that would likely result in adverse health effects due to drinking water.
>
> Sodium is another essential nutrient used by the body to control blood pressure and volume. In addition, sodium helps the muscles and nerves function properly. However, too much sodium can cause high blood pressure. ATSDR calculated daily intakes of sodium according to the highest detected concentration in drinking water wells. Adults who drink 3 liters of water from Well 3–7 receive an additional 687 mg of sodium each day they

drink from that well. For comparison, residents who drink 3 liters of water from the public water supply system are ingesting only an additional 30 mg of sodium a day. FDA's Daily Value for sodium is 2,400 mg (USDA and USDHHS 2000). Residents drinking water from a well with elevated sodium levels should be aware that their sodium intakes are increasing and should modify their diets accordingly. People who already have elevated blood pressure or who are on a sodium-restricted diet should avoid drinking water from wells with elevated sodium levels. Determining whether the additional sodium intake will adversely affect a person's health is strictly an individual determination based on that person's diet and health status. Residents concerned about their intake of sodium, should seek advice from their physician.

Another element detected in the water is boron, which occurs naturally in rocks. It is naturally released to the environment through the weathering process of rocks that contain boron. Various organs in the human body can be harmed if large amounts of boron are consumed (e.g., greater than 4,000,000 ppb) [ATSDR 1992]. ATSDR calculated doses of boron from drinking 3 liters of water (1.5 liters per day for children) on a daily basis from the well with the highest concentration. ATSDR compared the calculated intake levels to available health guidance values and found that the conservative doses were well below levels that would be likely to cause adverse health effects.

<u>Organics:</u>

Two wells in the Esperanza aquifer (one of the B wells and Navy Well 14) contained traces of one organic compound, chloroform. The levels of chloroform were well below EPA's MCL. Additionally, the calculated intakes, even over a lifetime of usage, are well below a level that would produce any adverse health effects. Please refer to Appendix D for further details concerning how ATSDR estimated exposure doses and determined health effects.

Although the source of the benzene and toluene in Navy Well 17 is unknown, the levels are far below the MCL. A lifetime of water usage from this well would not result in drinking enough of these compounds to produce any adverse health effects.

The two former Navy supply wells (Navy Well 14 and Navy Well 17) had di-n-butylphthalate reported in the samples. Di(2-ethylhexyl)phthalate was present in Well 3–7. As components of many plastics and common laboratory contaminants, these chemicals are probably not actually present in the drinking water. However, even assuming their presence, the levels found are not of health concern. A lifetime exposure to the maximum amount found in these samples does not increase the risk of any adverse health effects.

Well Construction:

EPA is concerned that the construction of Well 2-3 and Well 3-7 is inadequate to protect the water from surface runoff. ATSDR evaluated the chemical data gathered from these wells and found only the nitrate plus nitrite level in Well 3-7 to pose a health concern. ATSDR agrees with EPA that the poor well construction could potentially lead to contamination in the future.

Question 3: Is water from rainfall collection systems safe to drink?

Answer:

> Additional data need to be gathered in order to answer this question adequately. Historical data may not exist to provide a full answer to this question for past exposures.

Discussion:

Drinking Water Supply:

Some private residences may have rainfall collection systems to supplement their drinking water supply. In 1995, it was reported that the rainfall collection systems were a second source of freshwater, although the authors did not specify if the basins were used for drinking water supplies (Cherry and Ramos 1995). It is ATSDR's understanding that most of these basins have been converted into closed tanks that are supplied with public water. However, some residents may still use rainwater from rainfall collection systems in addition to the public water supply. In a 1998 sanitation survey for Vieques, 541 cisterns and tanks were identified (DOH 1998). These tanks may be used for water storage from the public water system, although some may be used in conjunction with rainfall collection systems.

Sampling Summary:

No sampling has been conducted to analyze drinking water from rainfall collection systems. In a 1978 study (see the discussion for Question 4), it was reported that one of the drinking water samples was diluted with rainwater (presumably from the use of rainfall collection system). This one sample point does not provide sufficient data to determine the impact on water quality from potential aerial dispersion of LIA-generated contaminants.

Water Quality:

Because no data are available on the rainfall collection systems, the associated water quality cannot be determined at this time. However, collected rainfall could contain substances from several different sources. Any dust, debris, or chemicals that might collect on the roof between rainfalls could be washed into the collection container unless provisions are made to ensure that the initial rainfall runoff, that rinses potential contaminants off the roof or collection surface, is not collected in the storage container. Otherwise, the water quality in the collection basin would reflect what was in the dust or other contaminants that fell on the collection surface between rainfalls.

ATSDR is in the process of evaluating whether airborne chemicals may travel across Vieques during Navy operations at the LIA. Winds on Vieques generally blow from east to west, potentially carrying dust and chemicals in the direction of populated areas. However, no data are available to quantify what chemicals might be transported across the island. Soil samples from the LIA are currently being analyzed to provide information on what chemicals are at the surface of the LIA. Historical information about weapons usage is also being gathered and an air dispersion model is in development to help provide estimates about how far chemicals may travel.

The seasonal African dust storms are also a major source of dust on both Vieques and the main island of Puerto Rico. The volume of dust as well as the metals that may be contained in the dust will also be evaluated. Finally, local use of pesticides over the years may have resulted in pesticides being deposited on collection areas and washed into collection basins.

Evaluation of the Impact of Water Quality on Public Health:

This potential impact on public health cannot be evaluated at this time because ATSDR does not have information about the location, use, or extent of contamination in rainfall collection systems. This question will be evaluated once data become available.

V. COMMUNITY HEALTH CONCERNS

An integral part of the public health assessment process is to address concerns of the community related to environmental health. Throughout the public health assessment process, ATSDR has been working and will continue to work with the community to define specific health issues of concern. On multiple trips to the island, ATSDR has met with a variety of individuals and organizations, including local officials, physicians, nurses, pharmacists, leaders of women's groups, school educators, fishermen, and businessmen. ATSDR has also met with individual families to understand their health concerns. Meeting with community members is critical to determine health issues of concern and to assess the environmental health issues on Vieques.

General issues of health concern related to drinking water have been assessed in this public health assessment. Public health issues related to potential exposure pathways involving contaminant transport through the air or food chain are currently being evaluated by ATSDR.

As discussed in this document, evaluation of drinking water supplied by rainfall collection systems is not complete. Any information provided by the community about the past or current usage of such systems will be helpful in our continued evaluations.

Community members can direct their health concerns to:

Program Evaluation and Records Information Services Branch
ATSDR, Division of Health Assessment and Consultation
Attn: Isla de Vieques, Puerto Rico
1600 Clifton Road, NE (E-56)
Atlanta, Georgia 30333

Community members can also telephone our regional representatives in New York, New York, at (212) 637-4307 or call our toll-free telephone number, 1-888-42-ATSDR.

VI. ATSDR CHILD HEALTH INITIATIVE

ATSDR recognizes that infants and children may be more sensitive to environmental exposure than adults in communities faced with contamination of their water, soil, air, or food. This sensitivity is a result of the following factors: 1) children are more likely to be exposed to certain media (e.g., soil or surface water) because they play outdoors; 2) children are shorter than adults, which means that they can breathe dust, soil, and vapors close to the ground; and 3) children are smaller, therefore childhood exposure results in higher doses of chemical exposure per body weight. Children can sustain permanent damage if these factors lead to toxic exposure during critical growth stages. ATSDR is committed to evaluating their special interests at sites such as Vieques as part of the its Child Health Initiative.

Based on a thorough review of the available data pertaining to drinking water for the residents of Vieques, ATSDR concludes the following concerning children:

- If children drink water from Well 3–7, they may be exposed to harmful levels of nitrates and/or nitrites which can cause serious health effects for children because nitrite interferes with oxygen uptake in blood (EPA 1995). Children, especially infants, should not drink water from this well. PRDOH has issued a health advisory for Well 3–7 and informed residents that water from this well is not safe to drink. For a full discussion on the exposure potential, please read the "Nitrate/Nitrite" section in the "Evaluation of the Impact of Water Quality on Public Health" discussion under "Question 2: Is the groundwater on Vieques safe to drink?".

- ATSDR did not identify any other situations that would result in adverse health effects in children from the drinking water pathway.

- ATSDR is also addressing the needs of children through educational efforts about environmental health and other health issues in the schools. As mentioned in the public health action plan, ATSDR has initiated work with school officials to identify and address environmental health educational needs of children and families.

VII. CONCLUSIONS

This PHA considers use of water resources as a sole source of drinking water over a lifetime. However, the evaluations and therefore the conclusions discussed in this section do not yet include any contribution from other sources of contamination that the residents of Vieques may encounter. As other sources are investigated, any additional exposures will be evaluated in conjunction with these findings to determine cumulative effects.

ATSDR has categorized this site as having **no apparent public health hazard**. In evaluating exposures to contaminants found in Well 3-7, ATSDR concluded this well posed a public health hazard; however, PRDOH issued an advisory for this well and notified the residents not to use it to supply drinking water. Because no data are currently available, ATSDR concludes that rainfall collection systems pose an indeterminate public health hazard. (Definitions of public health categories are included in the glossary in Appendix A.) Conclusions regarding the drinking water sources evaluated by ATSDR are as follows:

- The majority of the residents receive their drinking water from the mainland of Puerto Rico. Three different agencies tested the drinking water within the public water supply system. After an evaluation of the results of these tests, ATSDR concludes that ***the public drinking water supply is not being impacted by the bombing range activities and is safe to drink.***

- Groundwater cannot travel from the LIA across the island to residential areas of the island. Therefore, ***groundwater from the LIA is not impacting groundwater in the residential area of Vieques.***

- Some residents may supplement their drinking water supply by using water from groundwater wells. EPA and PRDOH sampled various groundwater wells and ATSDR evaluated the results. ***The water from the three Sun Bay wells, the four B wells, and Well 2–3 is safe to drink*** whenever the public water supply is interrupted. However, residents who are on a sodium-restricted diet should be cautious when drinking water from these wells.

- One private well (Well 3–7) showed high levels of nitrates plus nitrites. ***The water from Well 3-7 is not safe to drink***, especially for children and pregnant women. In October 1999, PRDOH issued an advisory and personally informed residents that water from this well is not safe for consumption. ATSDR agrees that residents, especially children and pregnant women, should not drink the water from Well 3–7. Because of the hydrogeology of the island and analysis of other groundwater wells in the area, ATSDR does not believe that the high level of nitrates plus nitrites in groundwater is a consequence of the bombing range activities; rather, it is probably a result of agricultural activities or septic systems in the area.

- The location, use, and extent of contamination in rainfall collection systems are not available. Therefore, ***the potential impact from drinking water from rainfall collection systems cannot be evaluated at this time***. ATSDR's evaluation of the air pathway will provide additional insight into this potential exposure route.

- Very low levels of RDX, tetryl, ammonia, and nitrate plus nitrite may have been present in drinking water samples taken by the Navy in 1978. However, ATSDR has doubts about the validity of the data because of the small number and description of the samples. The authors of the report noted that "a completely positive identification was not possible due to the extremely low concentrations found" (Hoffsommer and Glover 1978). The levels of nitrate plus nitrite are consistent with groundwater on the island and are not conclusive evidence of explosive contamination. In addition, more recent analyses of drinking water samples did not detect any explosive related contamination. ***The concentrations of explosive compounds reported in drinking water in the past were well below levels considered harmful to human health and past exposure to these compounds does not pose a public health hazard.***

- There is no evidence that residents of Vieques have been exposed to additional levels of radiation as a result of the February 1999 use of depleted uranium (DU) rounds in the LIA. Based on samples taken from across Vieques, the NRC concluded that there was no spread of DU to areas outside the LIA. ***The levels of radiation detected in soil, vegetation, and water by the NRC investigators are consistent with normal radiation background levels and do not represent a public health hazard.***

VIII. PUBLIC HEALTH ACTION PLAN

The Public Health Action Plan for Vieques contains a description of actions taken and those to be taken by ATSDR, the Navy, EPA, PREQB, and PRDOH. The purpose of the Public Health Action Plan is to ensure that this PHA not only identifies public health hazards, but also provides a plan of action to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment. The public health actions that are completed, planned, or recommended are as follows:

Actions Completed:

- Drinking water and groundwater sampling was carried out by various agencies, including EPA, PRDOH, PREQB, USGS, and the Navy.

- In August 1999, ATSDR conducted an initial site visit to Vieques to meet with the petitioner, tour the island and bombing range, and gather available environmental data. As a result of this site visit, ATSDR accepted the resident's petition and initiated the PHA process.

- In September 2000, ATSDR met with various agencies including PRDOH, PREQB, EPA, USGS, and the Navy to gather data and to discuss the scope and nature of ATSDR investigations. ATSDR also met with the petitioner to tour various sites on Vieques and provide an update on ATSDR efforts.

- In June and October 2000, ATSDR discussed with local health care providers their concerns about public health and provided training about how to medically assess environmental exposures. During these visits ATSDR met with numerous residents of the island to discuss health concerns.

- In September 2001, ATSDR conducted additional community involvement activities to inform participants of the scope of ATSDR investigations and seek additional community input. Continuing education-public health training was held for the nurses of Vieques and environmental health instruction was given to area parents and high school students.

- ATSDR held a public availability session on March 14, 2001 to be available to meet individually with community members about the findings of the evaluation of drinking water on Vieques.

Actions Planned:

- ATSDR will continue to identify and analyze potential and completed pathways as data become available and will impart the findings to the residents of Vieques in additional focused PHAs.

Recommendations for Further Action:

- Because the levels of nitrate and nitrite in Well 3-7 is a public health hazard and because there may be other similar shallow domestic drinking water wells in use that have not been identified, ATSDR recommends that when such wells are identified that PRDOH or PREQB sample those wells to ensure that the well water is safe to drink.

- It is known that some rainfall collection systems are installed on Vieques. The available information indicates that most of these systems are used to provide an emergency water supply. However, some rainfall collection systems may be used for a more continuous drinking water supply. ATSDR recommends that PRDOH or PREQB identify examples of such collection systems and perform sampling to evaluate if these systems deliver tap water that is safe to drink. If the storage tanks associated with these collection systems contain bottom sediments, it is recommended that those sediments be sampled to provide an indication of potential past water quality.

- ATSDR recommends that PRDOH or PREQB, in coordination with Compania de Aguas, take the necessary steps to ensure that backup water supply systems are available during emergency situations.

Other Public Health Assessment Activities

Completed or Ongoing Actions:

- ATSDR will continue to identify and analyze potential pathways as data become available and will impart the findings to the residents of Vieques in additional focused PHAs. Efforts are ongoing to assess potential pathways of contaminant transport through the air, soil, and food chain. Reports on these evaluations will be made available for public comment when they are completed.

- ATSDR requested that the Navy sample soil on the LIA for use in our assessment of the air and soil pathways. This sampling has been completed and was received by ATSDR in early January 2001. Evaluation of those data is underway.

- ATSDR is continuing to meet with various community members and organizations to gather concerns and exchange information. This effort will continue throughout the PHA process.

- ATSDR has and will continue to meet with local health care providers to discuss health concerns for the community and to provide educational materials for addressing the community's health needs.

- ATSDR will review cancer registry information and data gathered by the PRDOH. The information will be evaluated as it relates to potential pathways of environmental exposure and general health status of the communities.

- PRDOH is working on Vieques to gather information about recent cancer cases on the island. The information gathered will be added to the current cancer registry information.

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TABLES

Table 1. Summary of Pathways Evaluated in this Public Health Assessment

Pathway Name	Exposure Pathway Elements						Comments
	Potential Source of Contamination	Environmental Media	Point of Exposure	Route of Exposure	Exposed Population	Time of Exposure	
Potential Exposure Pathways							
Drinking water from the public water supply system	None	None The pipeline water supply in Vieques storage tanks is not contaminated	None	None	None	None	The source of the public water is the Rio Blanco, located on the main island of Puerto Rico. There is no reasonable pathway that would connect bombing activities at the LIA with the Rio Blanco.
Drinking water from groundwater wells in the residential area	Bombing at the LIA and open burning/open detonation activities	Groundwater	None Groundwater under the LIA cannot reach drinking water wells.	None	None	None	There is no hydrogeological connection between groundwater at the LIA and the residential area of the island.
		Air → Soil → Groundwater	None Public and private drinking water wells show no contaminants at levels that would cause illness.	None	None	None	Recent sampling did not detect explosives or explosive residues in the groundwater.

Table 1. Summary of Pathways Evaluated in this Public Health Assessment (continued)

Pathway Name	Exposure Pathway Elements						Comments
	Potential Source of Contamination	Environmental Media	Point of Exposure	Route of Exposure	Exposed Population	Time of Exposure	
Potential Exposure Pathways							
Drinking water from rainwater collection systems	Bombing at the LIA and open burning/open detonation activities	Air → deposition in rainfall collection systems	Household use of water from rainfall collection systems	Dermal Contact Ingestion Inhalation	Residents of Vieques using rainfall collection systems	Past, current, and future	Additional information is needed on use of past and current rainfall collection systems. Potential of air transport and deposition of contaminants into collection systems is being assessed by evaluating the potential air pathway. ATSDR will address the air pathway and the potential for deposition into the rainfall collection systems in a future focused public health assessment.
Past drinking water sources	Explosives potentially from military activities	Groundwater or Storage tanks	Drinking water	Dermal Contact Ingestion Inhalation	Residents of Vieques	Past	Although levels of explosives were reported in sampling from 1978, their presence was not conclusive and the data are uncertain. However, even if present at levels reported, these contaminants were well below levels considered harmful to human health.

Table 1. Summary of Pathways Evaluated in this Public Health Assessment (continued)

Pathway Name	Exposure Pathway Elements						Comments
	Potential Source of Contamination	Environmental Media	Point of Exposure	Route of Exposure	Exposed Population	Time of Exposure	
			Exposure Pathway of Health Concern				
Drinking water from Well 3-7	Agricultural contamination	Groundwater supplying drinking water well.	Household use of water from well.	Ingestion Inhalation	Users of well.	Past, current?, and future?	Nitrates plus nitrites potentially from agricultural sources have contaminated the well. The PRDOH has advised residents of health concerns related to use of the well.

Table 2. Chemicals Detected in the Public Water Supply System

Chemical	Chemical Concentration Range (ppb)	Frequency of Detections	Frequency above Standards	Drinking Water Standards (ppb)
Metals				
Aluminum[a]	77	1/12	0	50–200*
Barium[b]	16	1/12	0	2,000†
Boron	13–22	9/11	NA	NA
Copper	13–45	2/11	0	1,300§
Iron	53–240	5/11	0	300*
Magnesium	3,700	1/1	NA	NA
Manganese	2–20	12/12	0	50*
Potassium	1,300	1/1	NA	NA
Sodium	8,800–9,900	12/12	NA	NA
Strontium	47	1/1	NA	NA
Zinc	9–36	5/12	0	5,000*
Volatile Organic Compounds				
Chlorodibromomethane	1.0–2.8	12/12	0	80‡
Chloroform	44–74	12/12	0	80‡
Dichlorobromomethane	10–14	12/12	0	80‡
4-Methyl-2-pentanone	2.6–3.3	2/11	NA	NA
Toluene	1.1	1/12	0	1,000†
Total Trihalomethanes	56–88	11/11	0	100†
Inorganics				
Ammonia	19	1/1	NA	NA
Chloride	20,100–25,000	12/12	0	250,000*

†MCL ‡ Proposed MCL * SMCL § MCLG

[a] EPA and PRDOH sampled with detection limits higher than the concentration detected by the Navy's contractor.
[b] PRDOH sampled with a detection limit higher than the concentration detected by the Navy's contractor.

Table 2. Chemicals Detected in the Public Water Supply System (continued)

Chemical	Chemical Concentration Range (ppb)	Frequency of Detections	Frequency above Standards	Drinking Water Standards (ppb)
Fluoride	30–70	2/12	0	4,000†
Nitrate	250	1/1	0	10,000†
Nitrate plus Nitrite	50–140	6/10	0	10,000†
Sulfate	5,050–8,100	11/11	0	250,000*
Total Dissolved Solids	87,000–110,000	10/10	0	500,000*

Di(2-ethylhexyl)phthalate was reported by the lab, but quality assurance/quality control data indicted it was an artifact of the sampling process and not considered representative of the water quality.

Reference: Baker 1999; EPA 1999b; PRDOH 1999

Abbreviations:
MCL = Maximum Contaminant Level (EPA)
MCLG = Maximum Contaminant Level Goal for drinking water (EPA)
NA = Not Available
ppb = parts per billion
SMCL = Secondary Maximum Contaminant Level (EPA)

†MCL ‡ Proposed MCL * SMCL § MCLG

[a] EPA and PRDOH sampled with detection limits higher than the concentration detected by the Navy's contractor.

[b] PRDOH sampled with a detection limit higher than the concentration detected by the Navy's contractor.

Table 3. Chemicals Detected in Groundwater Wells in the Esperanza Valley Aquifer

Chemical	Sun Bay Wells			B Wells			Navy Well 14			Drinking Water Standards (ppb)
	Range (ppb)	Frequency of Detections	Frequency above Standards	Range (ppb)	Frequency of Detections	Frequency above Standards	Range (ppb)	Frequency of Detections	Frequency above Standards	
Metals										
Barium	ND	0/6	0	ND	0/4	0	210	1/1	0	2,000†
Beryllium	ND	0/6	0	ND	0/4	0	0.45	1/1	0	4†
Boron	203–226	3/3	NA	NS	-	-	NS	-	-	NA
Calcium	NS	-	-	NS	-	-	85,000	1/1	NA	NA
Copper	ND	0/6	0	ND	0/4	0	27	1/1	0	1,300§
Iron	1,060–2,150	3/6	3	ND	0/4	0	ND	0/1	0	300*
Lead	ND	0/6	0	ND	0/4	0	1.9	1/1	0	15†
Manganese	60–528	5/6	5	ND	0/4	0	1	1/1	0	50*
Molybdenum	ND	0/3	0	NS	-	-	ND	0/1	0	NA
Sodium	103,000–120,000	6/6	NA	158,000–195,000	4/4	NA	140,000	1/1	NA	NA
Vanadium	NS	-	-	NS	-	-	7.5	1/1	NA	NA
Zinc	5–24	3/6[a]	0	ND	0/4	0	31	1/1	0	5,000*
Volatile Organic Compounds										
Chloroform	ND	0/9	0	1.3–1.6	2/8	0	1.6	1/1	0	80‡
Total Trihalomethanes	ND	0/6	0	2.9	1/4	0	NS	-	-	100†

†MCL ‡ Proposed MCL * SMCL § MCLG

[a] Three of the six samples were below detection limits of 60 ppb.

Table 3. Chemicals Detected in Groundwater Wells in the Esperanza Valley Aquifer (continued)

Chemical	Sun Bay Wells			B Wells			Navy Well 14			Drinking Water Standards (ppb)
	Range (ppb)	Frequency of Detections	Frequency above Standards	Range (ppb)	Frequency of Detections	Frequency above Standards	Range (ppb)	Frequency of Detections	Frequency above Standards	
Semi-volatile Organic Compounds										
Di-n-butylphthalate	ND	0/6	0	ND	0/4	0	0.37	1/1	NA	NA
Inorganics										
Chloride	78,000–102,000	6/6	0	64,000–113,000	4/4	0	260,000	1/1	1	250,000*
Fluoride	500	1/4	0	570–670	4/4	0	150	1/1	0	4,000†
Ortho-Phosphate	NS	-	-	NS	-	-	720	1/1	NA	NA
Sulfate	31,000–39,700	6/6	0	48,000–77,000	4/4	0	47,000	1/1	0	250,000*
Nitrate	1,600–2,100	3/3	0	540–1,700	5/5	0	11,000	1/1	1	10,000†
Nitrite	ND	0/6	0	ND	0/4	0	50	1/1	0	1,000†
Nitrate plus Nitrite	260–1,860	3/3	0	NS	-	-	NS	-	-	10,000†
Total Dissolved Solids	90,500–1,670,000	6/6	3	534,000–658,000	4/4	4	790,000	1/1	1	500,000*

References: EPA 1999b, PRDOH 1995a,b; Baker 1999

Abbreviations:
MCL = Maximum Contaminant Level (EPA)
SMCL= Secondary Maximum Contaminant Level (EPA)
NA = Not Available
ND = Not Detected
NS = Not Sampled
ppb = parts per billion

†MCL ‡ Proposed MCL * SMCL § MCLG

[a] Three of the six samples were below detection limits of 60 ppb.

Table 4. Chemicals Detected in Groundwater Wells in the Resolucion Aquifer

Chemical	Former Navy Wells in NASD			Drinking Water Standards (ppb)
	Range (ppb)	Frequency of Detections[a]	Frequency above Standards	
Metals				
Barium	130	1/1	0	2,000†
Beryllium	0.79	1/1	0	4†
Calcium	14,000–71,000	6/6	NA	NA
Chromium	1.8	1/1	0	100†
Cobalt	2.4	1/1	NA	NA
Iron	800–5,000	6/6	6	300*
Lead	1.1	1/1	0	15 †
Magnesium	12,000–45,000	5/5	NA	NA
Manganese	32–540	6/6	5	50*
Nickel	2	1/1	0	100†
Sodium	160,000–168,000	6/6	NA	NA
Vanadium	3.3	1/1	NA	NA
Zinc	3.7–30	3/6	0	5,000*
Volatile Organic Compounds				
Benzene[a]	21	1/1	1	5†
Chloroform	0.74–6.2	3/4	0	80‡
Toluene[b]	0.22	1/1	0	1,000†
Semi-volatile Organic Compounds				
Di-n-butylphthalate	0.56	1/1	NA	NA
Siloxane	1.1–1.9	2/3	NA	NA

†MCL ‡ Proposed MCL * SMCL

[a] One of the five wells was sampled by both the Navy's contractor and USGS; the remaining four were only sampled by USGS.

[b] The chemical was not detected in the duplicate of this sample.

Table 4. Chemicals Detected in Groundwater Wells in the Resolucion Aquifer (continued)

Chemical	Former Navy Wells in NASD			Drinking Water Standards (ppb)
	Range (ppb)	Frequency of Detections[a]	Frequency above Standards	
Sanitary Analytes				
Chloride	76,000–380,000	6/6	1	250,000*
Fluoride	200	1/6	0	4,000†
Ortho-Phosphate	41	1/1	NA	NA
Sulfate	15,000–38,000	6/6	0	250,000*
Total Dissolved Solids	790,000	1/1	1	500,000*
Nitrate	55–1,700	6/6	0	10,000†
Nitrite	19	1/1	0	1,000†
Other				
Gross Beta	5.97 pCi/L	1/1	0	15 pCi/L†

Reference: Baker 1999; USGS 1997

Abbreviations:
MCL = Maximum Contaminant Level (EPA)
MCLG = Maximum Contaminant Level Goal for drinking water (EPA)
NA = Not Available
ND = Not Detected
pCi/L = picocurries per liter
ppb = parts per billion
SMCL = Secondary Maximum Contaminant Level (EPA)

†MCL ‡ Proposed MCL * SMCL

[a] One of the five wells was sampled by both the Navy's contractor and USGS; the remaining four were only sampled by USGS.

[b] The chemical was not detected in the duplicate of this sample.

Table 5. Chemicals Detected in Other Groundwater Resources

Chemical	Well 3-7			Well 2-3			Drinking Water Standards (ppb)
	Range (ppb)	Frequency of Detections	Frequency above Standards	Range (ppb)	Frequency of Detections	Frequency above Standards	
Metals							
Barium	267	1/1	0	ND	0/1	0	2,000†
Boron	280	1/1	NA	264	1/1	NA	NA
Manganese	27	1/1	0	25	1/1	0	50*
Molybdenum	ND	0/1	0	0.05	1/1	NA	NA
Sodium	229,000	1/1	NA	172,000	1/1	NA	NA
Zinc	6	1/1	0	14	1/1	0	5,000*
Inorganics							
Chloride	242,000	1/1	0	202,000	1/1	0	250,000*
Sulfate	62,400	1/1	0	63,000	1/1	0	250,000*
Nitrate plus Nitrite	1,700–12,60 0	2/2	1	500–1,330	2/2	0	10,000†
Total Dissolved Solids	1,330,000	1/1	1	1,220,000	1/1	1	500,000*

References: EPA 1999b; EPA 2000

Di(2-ethylhexyl)phthalate was reported by the lab, but quality assurance/quality control data indicted it was an artifact of the sampling process and not considered representative of the water quality.

Abbreviations:
MCL = Maximum Contaminant Level (EPA)
NA = Not Available
ND = Not Detected
NS = Not Sampled
ppb = parts per billion
SMCL = Secondary Maximum Contaminant Level (EPA)

†MCL ‡ Proposed MCL * SMCL

FIGURES

Figure 1. **Location of Vieques**

Reference: Torres-Gonzalez, 1989

Figure 2. **Location of Alluvial Aquifers on Vieques**

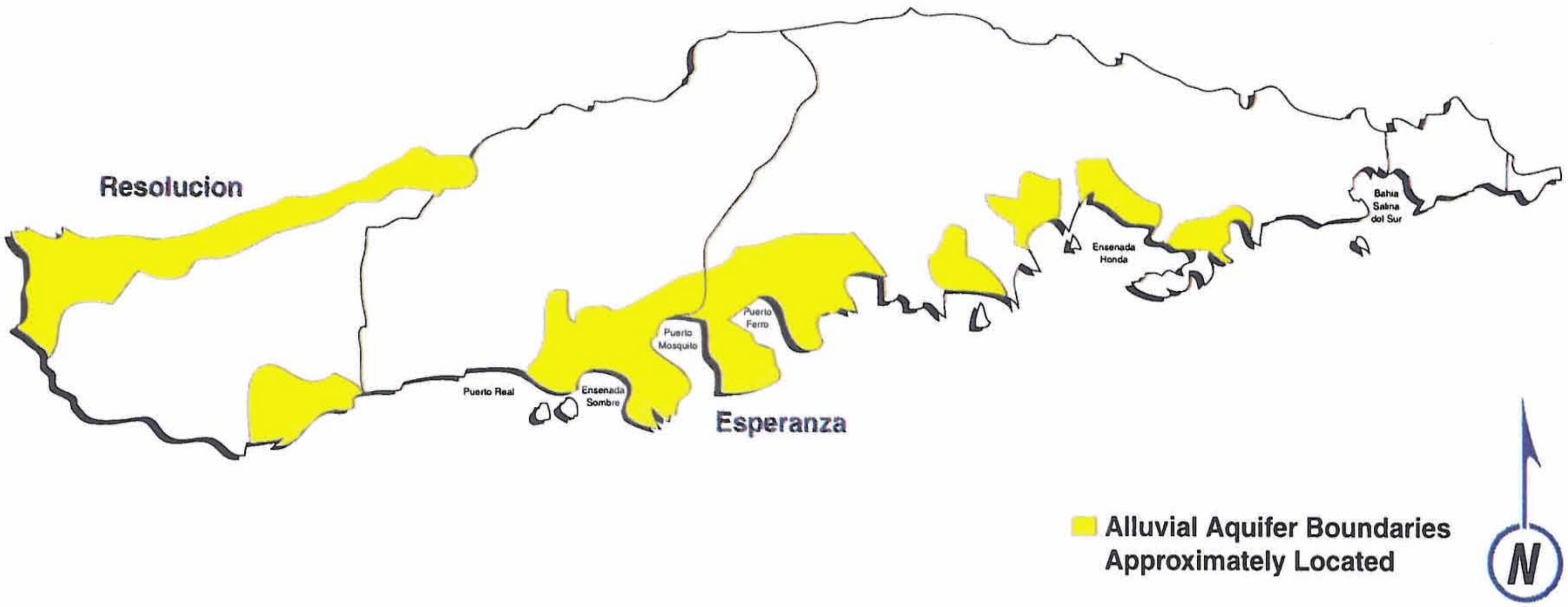


Figure 3. ATSDR's Exposure Evaluation Process

REMEMBER: For a public health threat to exist, the following three conditions must all be met:

- People must come into contact with areas that have potential contamination
- Contaminants must exist in the environment
- The amount of contamination must be sufficient to affect people's health

Are People Exposed To Areas With Potentially Contaminated Media?

For exposure to occur, contaminants must be in locations where people can contact them.

People may contact contaminants by any of the following three exposure routes:

Inhalation
Ingestion
Dermal absorption

Are the Environmental Media Contaminated?

ATSDR considers:

Soil
Ground water
Surface water and sediment
Air
Food sources

For Each Completed Exposure Pathway, Will the Contamination Affect Public Health?

ATSDR will evaluate existing data on contaminant concentration and exposure duration and frequency.

ATSDR will also consider individual characteristics (such as age, gender, and lifestyle) of the exposed population that may influence the public health effects of contamination.

Figure 4. **Locations of Public Water Supply Tanks on Vieques**

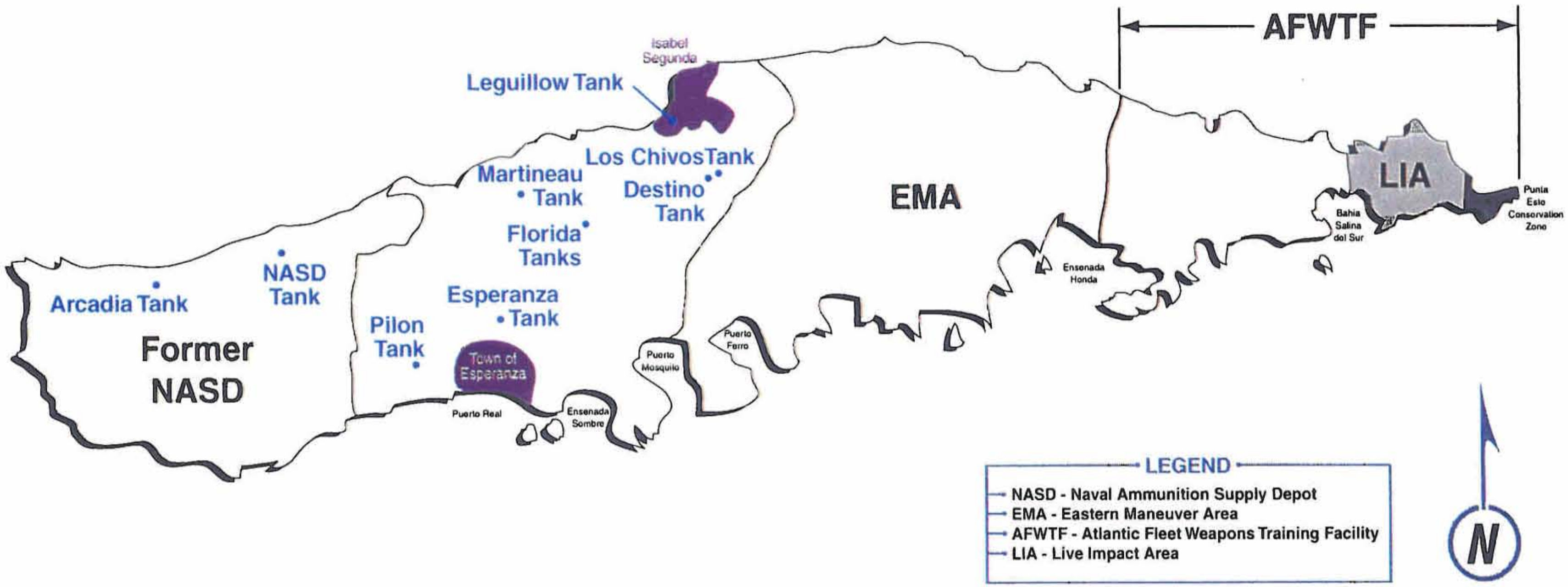
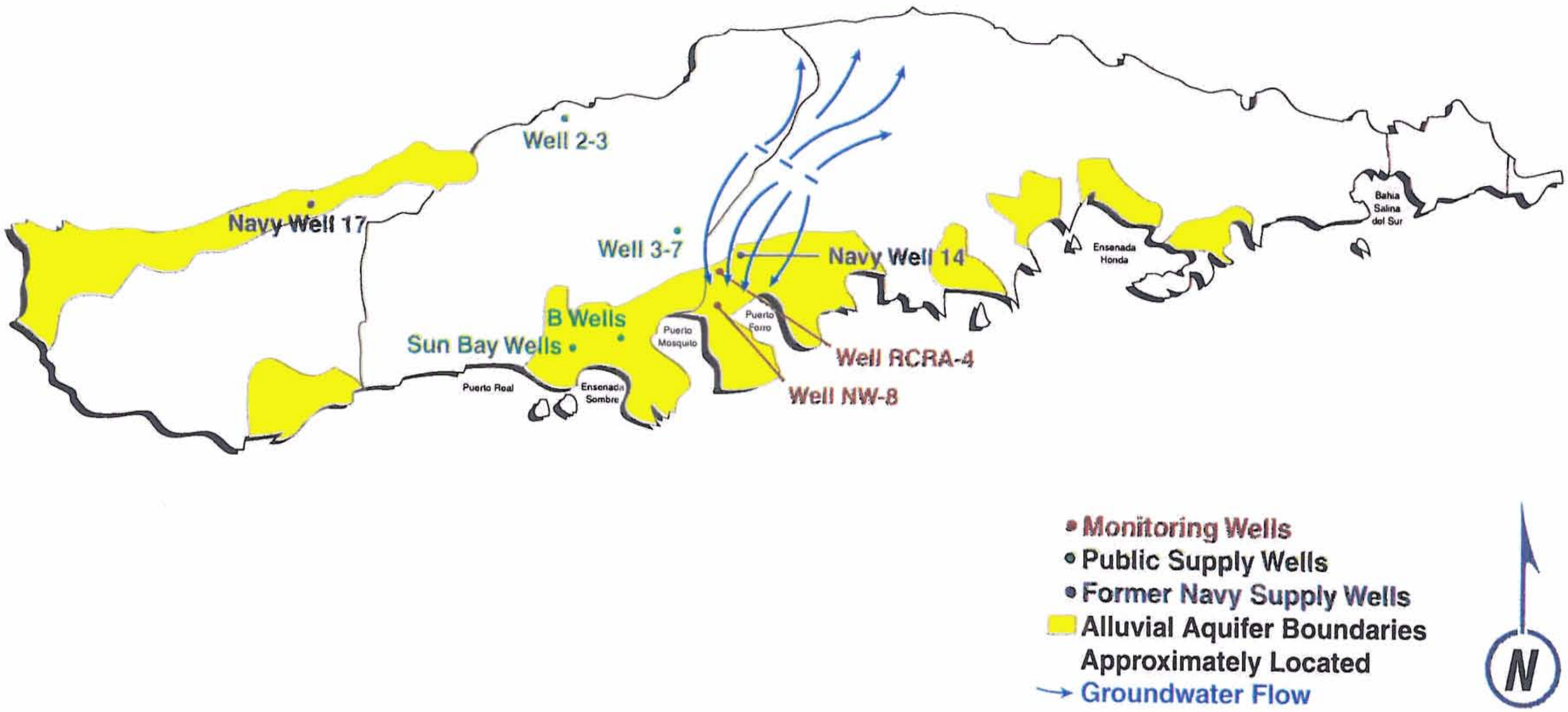


Figure 5. **Locations of Groundwater Wells on Vieques**



APPENDICES

APPENDIX A

Glossary

ATSDR Plain Language Glossary
of Environmental Health Terms

Adverse Health Effect: A change in body function or the structures of cells that can lead to disease or health problems.

ATSDR: The Agency for Toxic Substances and Disease Registry. ATSDR is a federal health agency in Atlanta, Georgia that deals with hazardous substance and waste site issues. ATSDR gives people information about harmful chemicals in their environment and tells people how to protect themselves from coming into contact with chemicals.

Biota: Used in public health, things that humans would eat – including animals, fish and plants.

Cancer: A group of diseases which occur when cells in the body become abnormal and grow, or multiply, out of control

Carcinogen: Any substance shown to cause tumors or cancer in experimental studies.

Chronic Exposure: A contact with a substance or chemical that happens over a long period of time. ATSDR considers exposures of more than one year to be *chronic*.

Completed Exposure Pathway: See **Exposure Pathway**.

Comparison Value: (CVs) Concentrations or the amount of substances in air, water, food, and soil that are unlikely, upon exposure, to cause adverse health effects. Comparison values are used by health assessors to select which substances and environmental media (air, water, food and soil) need additional evaluation while health concerns or effects are investigated.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA): **CERCLA** was put into place in 1980. It is also known as Superfund. This act concerns releases of hazardous substances into the environment, and the cleanup of these substances and hazardous waste sites. ATSDR was created by this act and is responsible for looking into the health issues related to hazardous waste sites.

Concern: A belief or worry that chemicals in the environment might cause harm to people.

Concentration: How much or the amount of a substance present in a certain amount of soil, water, air, or food.

Contaminant: See **Environmental Contaminant**.

Dermal Contact: A chemical getting onto your skin. (see **Route of Exposure**).

Dose: The amount of a substance to which a person may be exposed, usually on a daily basis. Dose is often explained as "amount of substance(s) per body weight per day".

Dose / Response: The relationship between the amount of exposure (dose) and the change in body function or health that result.

Duration: The amount of time (days, months, years) that a person is exposed to a chemical.

Environmental Contaminant: A substance (chemical) that gets into a system (person, animal, or the environment) in amounts higher than that found in **Background Level**, or what would be expected.

Environmental Media: Usually refers to the air, water, and soil in which chemicals of interest are found. Sometimes refers to the plants and animals that are eaten by humans. **Environmental Media** is the second part of an **Exposure Pathway**.

U.S. Environmental Protection Agency (EPA): The federal agency that develops and enforces environmental laws to protect the environment and the public's health.

Epidemiology: The study of the different factors that determine how often, in how many people, and in which people will disease occur.

Exposure: Coming into contact with a chemical substance.(For the three ways people can come in contact with substances, see **Route of Exposure**.)

Exposure Assessment: The process of finding the ways people come in contact with chemicals, how often and how long they come in contact with chemicals, and the amounts of chemicals with which they come in contact.

Exposure Pathway: A description of the way that a chemical moves from its source (where it began) to where and how people can come into contact with (or get exposed to) the chemical.

ATSDR defines an exposure pathway as having 5 parts:

1. Source of Contamination,
2. Environmental Media and Transport Mechanism,
3. Point of Exposure,
4. Route of Exposure, and
5. Receptor Population.

When all 5 parts of an exposure pathway are present, it is called a **Completed Exposure Pathway**. Each of these 5 terms is defined in this Glossary.

Frequency: How often a person is exposed to a chemical over time; for example, every day, once a week, twice a month.

Hazardous Waste: Substances that have been released or thrown away into the environment and, under certain conditions, could be harmful to people who come into contact with them.

Health Effect: ATSDR deals only with **Adverse Health Effects** (see definition in this Glossary).

Indeterminate Public Health Hazard: The category is used in Public Health Assessment documents for sites where important information is lacking (missing or has not yet been gathered) about site-related chemical exposures.

Ingestion: Swallowing something, as in eating or drinking. It is a way a chemical can enter your body (See **Route of Exposure**).

Inhalation: Breathing. It is a way a chemical can enter your body (See **Route of Exposure**).

Inorganic: Compounds that do not contain hydrocarbon groups.

Isthmus: A narrow passage connecting two larger cavities.

LOAEL: Lowest Observed Adverse Effect Level. The lowest dose of a chemical in a study, or group of studies, that has caused harmful health effects in people or animals.

MCL: Maximum Contaminant Level. The standard set by EPA for drinking water within public water supply systems. EPA considers the protection of human health when setting the MCL.

MRL: Minimal Risk Level. An estimate of daily human exposure – by a specified route and length of time -- to a dose of chemical that is likely to be without a measurable risk of adverse, noncancerous effects. An MRL should not be used as a predictor of adverse health effects.

NPL: The National Priorities List. (Which is part of Superfund.) A list kept by the U.S. Environmental Protection Agency (EPA) of the most serious, uncontrolled or abandoned hazardous waste sites in the country. An NPL site needs to be cleaned up or is being looked at to see if people can be exposed to chemicals from the site.

NOAEL: No Observed Adverse Effect Level. The highest dose of a chemical in a study, or group of studies, that did not cause harmful health effects in people or animals.

No Apparent Public Health Hazard: The category is used in ATSDR's Public Health Assessment documents for sites where exposure to site-related chemicals may have occurred in the past or is still occurring but the exposures are not at levels expected to cause adverse health effects.

No Public Health Hazard: The category is used in ATSDR's Public Health Assessment documents for sites where there is evidence of an absence of exposure to site-related chemicals.

Ordnance: Military materiels such as weapons, ammunition, combat vehicles, and equipment.

Organic: Compounds containing carbon.

PHA: Public Health Assessment. A report or document that looks at chemicals at a hazardous waste site and tells if people could be harmed from coming into contact with those chemicals. The PHA also tells if possible further public health actions are needed.

Point of Exposure: The place where someone can come into contact with a contaminated environmental medium (air, water, food or soil). For examples: the area of a playground that has contaminated dirt, a contaminated spring used for drinking water, the location where fruits or vegetables are grown in contaminated soil, or the backyard area where someone might breathe contaminated air.

Population: A group of people living in a certain area; or the number of people in a certain area.

Public Health Hazard: The category is used in PHAs for sites that have certain physical features or evidence of chronic, site-related chemical exposure that could result in adverse health effects.

Public Health Hazard Criteria: PHA categories given to a site which tell whether people could be harmed by conditions present at the site. Each are defined in the Glossary. The categories are:

1. Urgent Public Health Hazard
2. Public Health Hazard
3. Indeterminate Public Health Hazard
4. No Apparent Public Health Hazard
5. No Public Health Hazard

Receptor Population: People who live or work in the path of one or more chemicals, and who could come into contact with them (See **Exposure Pathway**).

Reference Dose (RfD): An estimate, with safety factors (see **safety factor**) built in, of the daily, life-time exposure of human populations to a possible hazard that is not likely to cause harm to the person.

Route of Exposure: The way a chemical can get into a person's body. There are three exposure routes:

- breathing (also called inhalation),
- eating or drinking (also called ingestion), and
- or getting something on the skin (also called dermal contact).

Safety Factor: Also called Uncertainty Factor. When scientists don't have enough information to decide if an exposure will cause harm to people, they use "safety factors" and formulas in place of the information that is not known. These factors and formulas can help determine the amount of a chemical that is not likely to cause harm to people.

Semi-volatile organic compound (SVOC): A class of organic (carbon-containing) chemicals similar to VOCs, but that evaporate, or volatilize, less readily.

SMCL: The Secondary Maximum Contaminant Level is established based on secondary considerations such as taste, odor, and appearance, when health concerns are not an issue.

Source (of Contamination): The place where a chemical comes from, such as a landfill, pond, creek, incinerator, tank, or drum. Contaminant source is the first part of an **Exposure Pathway**.

Special Populations: People who may be more sensitive to chemical exposures because of certain factors such as age, a disease they already have, occupation, sex, or certain behaviors (like cigarette smoking). Children, pregnant women, and older people are often considered special populations.

Toxic: Harmful. Any substance or chemical can be toxic at a certain dose (amount). The dose is what determines the potential harm of a chemical and whether it would cause someone to get sick.

Toxicology: The study of the harmful effects of chemicals on humans or animals.

Tumor: Abnormal growth of tissue or cells that have formed a lump or mass.

Urgent Public Health Hazard: This category is used in ATSDR's Public Health Assessment documents for sites that have certain physical features or evidence of short-term (less than 1 year), site-related chemical exposure that could result in adverse health effects and require quick intervention to stop people from being exposed.

Volatile Organic Compound (VOC): A class of organic (carbon-containing) chemicals which readily evaporate, or volatilize. VOCs are frequently used as solvents, degreasing agents, and in other industrial applications.

APPENDIX B

Sampling Summaries

Table B-1. Sampling Summary of the Public Water Supply System on Isla de Vieques, Puerto Rico

Name	Location	Use	Sampling Agency	Chemicals Sampled: VOCs/ SVOCs	Inorganics/ Metals	Pesticides/ Herbicides	PCBs	Explosives	Date Sampled
Arcadia Tank	Naval Ammunitions Support Detachment (NASD)	Public water supply tank owned by Puerto Rico Aqueduct and Sewer Authority (PRASA)	Puerto Rico Department of Health (DOH)					✔	June 1999[a]
			United States Environmental Protection Agency (USEPA)	✔	✔			✔	September 1999 January 2000b
NASD Tank	NASD	Navy water supply tank (water is supplied from the mainland)	USEPA	✔	✔			✔	September 1999 January 2000b
			The Navy's contractor	✔	✔			✔	September 1999
Pilon Tank	Pilon	Public water supply tank owned by PRASA	USEPA	✔	✔			✔	September 1999 January 2000[b]
Esperanza Tank	Esperanza	Public water supply tank owned by PRASA	Puerto Rico DOH					✔	June 1999[a]
			USEPA	✔	✔			✔	September 1999 January 2000[b]
Florida Tanks (2)	Florida	Public water supply tank owned by PRASA	Puerto Rico DOH					✔	June 1999[a]
			USEPA	✔	✔			✔	September 1999 January 2000[b]

[a] PR DOH also sampled for nitrate and nitrite.
[b] USEPA only sampled for explosives.

Table B-1. Sampling Summary of the Public Water Supply System on Isla de Vieques, Puerto Rico (continued)

Name	Location	Use	Sampling Agency	Chemicals Sampled: VOCs/ SVOCs	Inorganics/ Metals	Pesticides/ Herbicides	PCBs	Explosives	Date Sampled
Martineau Tank	Martineau	Public water supply tank owned by PRASA	USEPA	✔	✔			✔	September 1999 January 2000[b]
Destino Tank	Destino	Public water supply tank owned by PRASA	USEPA	✔	✔			✔	September 1999 January 2000[b]
Leguillow Tank	West of Isabel Segunda	Public water supply tank owned by PRASA	USEPA	✔	✔			✔	September 1999 January 2000[b]
Los Chivos Tank	Los Chivos	Public water supply tank owned by PRASA	USEPA	✔	✔			✔	September 1999 January 2000[b]
Distribution Tank	Unknown	Public water supply tank owned by PRASA	Puerto Rico DOH					✔	June 1999[a]
Agencia Comercial	Baldorioty Street	Tap connected to the public water supply	Puerto Rico DOH	✔	✔	✔	✔	✔	June 1999
Rio Blanco Input & Output	Naguabo, Puerto Rico	Filtration plant for public water supply	USEPA					✔	January 2000

[a] PR DOH also sampled for nitrate and nitrite.
[b] USEPA only sampled for explosives.

Table B-2. Sampling Summary of Groundwater Wells on Isla de Vieques, Puerto Rico

Name	Location	Use	Sampling Agency	Chemicals Sampled					Date Sampled
				VOCs/ SVOCs	Inorganics/ Metals	Pesticides/ Herbicides	PCBs	Explosives	
Well 2–3	Martineau	Remote well used by the public when water supply is interrupted	United States Environmental Protection Agency (USEPA)	✔	✔			✔	September 1999 January 2000[a]
Well 3–7	Proyecto Barracon	Local well used by the public when the water supply is interrupted	USEPA	✔	✔			✔	September 1999 January 2000[a]
Sun Bay Wells (3)	Sun Bay	Emergency water supply wells owned by Puerto Rico Aqueduct and Sewer Authority (PRASA)	Puerto Rico Department of Health (DOH)	✔	✔	✔	✔		May 1995
			USEPA	✔	✔				September 1999
B Wells (4)	Sun Bay	Prior to their abandonment in 1978, these wells were part of the Esperanza valley well field	Puerto Rico DOH	✔	✔	✔	✔		May 1995
Navy Well 14	Camp Garcia	Former drinking water well	The Navy's contractor	✔	✔	✔	✔	✔	August 1999
Navy Wells (5)	NASD	Uncertain: one was a supply well (Navy Well 17)	The Navy's contractor	✔	✔	✔	✔	✔	August 1999
			U.S. Geological Survey	✔	✔	✔			November 1996
Monitoring Wells (11)	Along the Eastern Maneuver Area (EMA) western boundary	Monitoring	The Navy's contractor					✔	August 1999

[a] USEPA sampled for explosives and nitrate plus nitrite.

APPENDIX C

Sampled Chemicals

Sampled Chemicals

Volatile Organic Compounds	EPA 1999b	Baker 1999	PR DOH 1999	PR DOH 1995
1,1,1,2-Tetrachloroethane	✓	✓	✓	✓
1,1,1-Trichloroethane	✓	✓	✓	✓
1,1,2,2-Tetrachloroethane	✓	✓	✓	✓
1,1,2-Trichloroethane	✓	✓	✓	✓
1,1-Dichloroethane	✓	✓	✓	✓
1,1-Dichloroethylene	✓	✓	✓	
1,1-Dichloropropene	✓	✓	✓	
1,2,3-Trichlorobenzene	✓	✓	✓	✓
1,2,3-Trichloropropane	✓	✓	✓	✓
1,2,4-Trichlorobenzene	✓	✓	✓	✓
1,2,4-Trimethylbenzene	✓	✓	✓	✓
1,2-Dibromo-3-chloropropane	✓	✓	✓	✓
1,2-Dibromoethane	✓	✓	✓	✓
1,2-Dichloroethane	✓	✓	✓	✓
1,2-Dichloropropane	✓	✓	✓	
1,3,5-Trimethylbenzene	✓	✓	✓	✓
1,3-Dichlorobenzene	✓	✓	✓	
1,3-Dichloropropane	✓	✓	✓	
1,2-Dibromo-3-chloropropane		✓		
1,4-Dibromo-3-chloropropane		✓		
2,2-Dichloropropane	✓	✓	✓	
2-Butanone	✓	✓		
o-Chlorotoluene	✓	✓	✓	✓
2-Hexanone	✓	✓		
3-Chloropropene (Allylchloride)		✓		
p-Chlorotoluene	✓	✓	✓	✓
4-Methyl-2-pentanone	✓	✓		
Acenonitrile		✓		
Acetone	✓	✓		
Acrolein (Propenal)		✓		
Acrylonitrile	✓	✓		
Benzene	✓	✓	✓	✓
Bromobenzene	✓	✓	✓	✓
Bromochloromethane	✓	✓	✓	✓
Dichlorobromomethane	✓	✓	✓	✓
Bromoform	✓	✓	✓	✓
Bromomethane (Methyl bromide)	✓	✓	✓	✓
Butylbenzene	✓		✓	✓
Carbon disulfide	✓	✓		
Carbon tetrachloride	✓	✓	✓	✓
Chlorobenzene	✓	✓	✓	✓
Chloroethane	✓	✓	✓	✓

Volatile Organic Compounds	EPA 1999b	Baker 1999	PR DOH 1999	PR DOH 1995
Chloroform	✓	✓	✓	✓
Chloromethane (Methyl chloride)	✓	✓	✓	✓
Chloroprene		✓	✓	
cis 1,2-Dichloroethylene	✓	✓	✓	
cis 1,3-Dichloropropene	✓	✓	✓	✓
Chlorodibromomethane	✓	✓	✓	✓
Dibromochloropropane				✓
Dibromomethane (Methylene bromide)	✓	✓	✓	✓
Dichlorodifluoromethane		✓	✓	✓
Ethyl methacrylate		✓		
Ethylbenzene	✓	✓	✓	✓
Hexachlorobutadiene	✓	✓	✓	✓
Iodomethane (Methyl iodide)		✓		
Isobutanol (Isobutyl alcohol)		✓		
Isopropylbenzene	✓	✓	✓	✓
m&p-Xylenes		✓		✓
p-Xylenes				✓
Methacrylonitrile		✓		
Methyl methacrylate		✓		
Methylene chloride (Dichloromethane)	✓	✓	✓	✓
Naphthalene	✓	✓		✓
n-Propylbenzene	✓	✓	✓	✓
o-Xylene		✓		✓
Pentachlorethane		✓		
P-Isopropyltoluene	✓	✓	✓	✓
Propionitrile		✓		
sec-Butylbenzene	✓	✓	✓	✓
Styrene	✓	✓	✓	✓
Tertbutylbenzene	✓	✓	✓	✓
Tetrachloroethylene	✓	✓	✓	✓
Toluene	✓	✓	✓	✓
trans 1,2-Dichloroethylene	✓	✓	✓	
trans 1,3-Dichloropropene	✓	✓	✓	✓
trans-1,4-Dichloro-2-butene		✓		
Trichloroethylene	✓	✓	✓	✓
Trichlorofluoromethane	✓	✓	✓	✓
Vinyl acetate		✓		
Vinyl chloride	✓	✓	✓	✓
Xylenes (total)	✓	✓	✓	
Total Trihalomethanes	✓		✓	

Semi-volatile Organic Compounds	EPA 1999b	Baker 1999	PR DOH 1999	PR DOH 1995
1,2,4,5-Tetrachlorobenzene		✓		
1,2,4-Trichlorobenzene		✓		
1,2-Dichlorobenzene (o-Dichlorobenzene)	✓	✓	✓	✓
1,2-Diphenylhydrazine	✓			
1,3,5-Trinitrobenzene		✓		
1,3-Dichlorobenzene (m-Dichlorobenzene)	✓	✓		✓
1,4-Dichlorobenzene (p-Dichlorobenzene)	✓	✓	✓	✓
1,4-Dioxane		✓		
1,4-Naphthoquinone		✓		
1,4-Phenylenediamene (p-Phenylenediamene)		✓		
1-Dillate		✓		
1-Naphthylamine		✓		
2,3,4,6-Tetrachlorophenol		✓		
2,4,5-Trichlorophenol	✓	✓		
2,4,6-Trichlorophenol	✓	✓		
2,4-Dichlorophenol	✓	✓		
2,4-Dimethylphenol	✓	✓		
2,4-Dinitrophenol	✓	✓		
2,4-Dinitrotoluene	✓	✓		
2,6-Dichlorophenol		✓		
2,6-Dinitrotoluene	✓	✓		
2-Acetylaminofluorene		✓		
2-Chloroethyl vinyl ether	✓			
2-Chloronaphthalene	✓	✓		
2-Chlorophenol	✓	✓		
2-Diallate		✓		
2-Methyl naphthalene	✓	✓		
2-Naphthylamine		✓		
2-Nitroaniline (o-Nitroaniline)	✓	✓		
2-Nitrophenol (o-Nitrophenol)	✓	✓		
2-Picoline		✓		
3,3'-Dichlorobenzidine		✓		
3,3'-Dimethylbenzidine		✓		
3-Methylcholanthrene		✓		
3-Nitroaniline (m-Nitroaniline)	✓	✓		
4,6-Dinitro-2-methylphenol		✓		
4-Aminobiphenyl		✓		
4-Bromophenyl phenyl ether	✓	✓		
p-Chloro-m-cresol	✓	✓		
4-Chloroaniline (p-Chloroaniline)	✓	✓		
4-Chlorophenyl phenyl ether	✓	✓		
4-Nitroaniline (p-Nitroaniline)	✓	✓		
4-Nitroguinoline 1-oxide		✓		
4-Nitrophenol (p-Nitrophenol)	✓	✓		
5-Nitro-o-toluidine		✓		
7,12-Dimethylbenz(a)anthracene		✓		
Acenaphthene	✓	✓		
Acenaphthylene	✓	✓		
Acetophenone		✓		
alpha, alpha-Dimethylphenethylamine		✓		
Aniline		✓		
Anthracene	✓	✓		
Aramite (total)		✓		
Aramite-1		✓		
Aramite-2		✓		
1,2-Benzanthracene	✓	✓		
Benzo(a)pyrene	✓	✓	✓	✓
3,4-Benzofluoranthene (Benzo(b)fluoranthene)	✓	✓		
Benzoic acid	✓			
1,12-Benzoperylene (Benzo(g,h,i)perylene)	✓	✓		
11,12-Benzofluoranthene (Benzo(k)fluoranthene)	✓	✓		
Benzyl alcohol	✓	✓		
Bis(2-chloroethoxy) methane	✓	✓		
Bis(2-chloroethyl) ether	✓	✓		
Bis(2-chloroisopropyl) ether	✓			
Butyl benzyl phthalate	✓	✓		
Chrysene	✓	✓		
4-Methyl phenol (p-cresol)	✓	✓		
2-Methyl phenol (o-cresol)	✓			
di(2-ethylhexyl)adipate			✓	✓
Di(2-ethylhexyl)phthalate	✓	✓	✓	✓
Diethyl phthalate	✓			
Diallate (total)		✓		
1,2:5,6-Dibenzanthracene (Dibenzo(a,h)anthracene)	✓	✓		
Dibenzofuran	✓	✓		
Dimethyl phthalate	✓	✓		
Di-n-butylphthalate	✓	✓		
Di-n-octylphthalate	✓	✓		
Dinoseb (2-sec-Butyl-4,6-dinitrophenol)		✓		
Ditrosol (4,6-Dinitro-o-cresol)	✓			
Ethyl methanesulronate		✓		
Fluoranthene	✓	✓		
Fluorene	✓	✓		
Hexachlorobenzene	✓	✓	✓	✓
Hexachlorobutadiene	✓	✓		

Semi-volatile Organic Compounds	EPA 1999b	Baker 1999	PR DOH 1999	PR DOH 1995
Hexachlorocyclopentadiene	✓	✓	✓	✓
Hexachloroethane	✓	✓		
Hexachlorophene		✓		
Hexachloropropene		✓		
Ideno(1,2,3-c,d)pyrene	✓	✓		
Isophorone	✓	✓		
Isosafrole		✓		
m-Dinitrobenzene		✓		
Methapyrilene		✓		
Methyl methanesulfonate		✓		
Naphthalene	✓	✓	✓	
Nitrobenzene	✓	✓		
n-Nitrosodiethylamine		✓		
n-Nitrosodimethylamine		✓		
n-Nitrosodi-n-butylamine		✓		
n-Nitrosodi-n-propylamine	✓			
n-Nitrosodiphenylamine (Diphenylamine)	✓	✓		
n-Nitrosomethylethlamine		✓		
n-Nitrosomorpholine		✓		
n-Nitrosopeperidine		✓		
n-Nitrosopryrrolidine		✓		
o,o,o-Triethyl phosphorothioate		✓		
o-Toluidine		✓		
p-(Dimethylamino)azobenzene		✓		
Pentachlorobenzene		✓		
Pentachloronitrobenzene		✓		
Pentachlorophenol	✓	✓		
Phenacetin		✓		
Phenanthrene	✓	✓		
Phenol	✓	✓		
Pronamide		✓		
Pyrene	✓	✓		
Pyridine		✓		
Safrole		✓		

Metals	EPA 1999b	Baker 1999	PR DOH 1999	PR DOH 1995
Aluminum	✓	✓	✓	✓
Antimony	✓	✓	✓	✓
Arsenic	✓	✓	✓	✓
Barium	✓	✓	✓	✓
Beryllium	✓	✓	✓	✓
Boron	✓			
Cadmium	✓	✓	✓	✓
Calcium		✓		
Chromium	✓	✓	✓	✓
Cobalt		✓		
Copper	✓	✓	✓	✓
Iron	✓	✓	✓	✓
Lead	✓	✓	✓	✓
Manganese	✓	✓	✓	✓
Molybdenum	✓	✓		
Nickel	✓	✓	✓	✓
Selenium	✓	✓	✓	✓
Silver		✓	✓	✓
Sodium	✓	✓	✓	✓
Thallium	✓	✓	✓	✓
Vanadium		✓		
Zinc	✓	✓	✓	✓

Inorganics	EPA 1999b	Baker 1999	PR DOH 1999	PR DOH 1995
Chloride	✓	✓	✓	✓
Cyanide	✓	✓	✓	✓
Fluoride	✓	✓	✓	✓
Mercury	✓	✓	✓	✓
Nitrate		✓	✓	✓
Nitrite		✓	✓	✓
Nitrate plus Nitrite	✓			
ortho-Phosphate		✓		
Sulfate	✓	✓	✓	✓
Sulfide		✓		
Total Dissolved Solids	✓	✓	✓	✓

Pesticides	Baker 1999	PR DOH 1999	PR DOH 1995
3-Hydroxycarbofuran	✓	✓	✓
4,4'-DDD	✓		
4,4'-DDE	✓		
4,4'-DDT	✓		
Alachlor	✓	✓	✓
Aldicarb	✓	✓	✓
Aldicarb sulfone	✓	✓	✓
aldicarb sulfoxide	✓	✓	✓
Aldrin	✓	✓	✓
alpha-BHC	✓		
alpha-Chlordane	✓		
Atrazine	✓	✓	✓
beta-BHC	✓		
Carbaryl	✓	✓	✓
Carbofuran	✓	✓	✓
Chlordane	✓	✓	✓
Chlorobenzilate	✓		
delta-BHC	✓		
Dicamba		✓	✓
Dieldrin	✓	✓	✓
Dimethoate	✓		
Disulfoton	✓		
Endosulfan I	✓		
Endosulfan II	✓		
Endosulfan sulfate	✓		
Endothall	✓	✓	✓
Endrin	✓	✓	✓
Endrin aldehyde	✓		
Endrin ketone	✓		
Ethyl parathion (Parathion)	✓		
Famphur	✓		
g-BHC (Lindane)	✓	✓	✓
gamma-Chlordane	✓		
Glyphosate	✓	✓	✓
Heptachlor	✓	✓	✓
Heptachlor epoxide	✓	✓	✓
Isodrin	✓		
Kepone	✓		
Methiocarb		✓	
Methomyl	✓	✓	✓
Methoxychlor	✓	✓	✓
Methyl parathion	✓		
Metolachlor		✓	✓
Metribuzin		✓	✓
Oxamyl	✓	✓	✓
Phorate	✓		
Propachlor		✓	✓

Pesticides	Baker 1999	PR DOH 1999	PR DOH 1995
Simazine	✓	✓	✓
Sulfotepp (Tetraethyl dithiopyrophosphate)	✓		
Thionazin	✓		
Toxaphene	✓	✓	✓

Herbicides	Baker 1999	PR DOH 1999	PR DOH 1995
2,4,5-T	✓	✓	✓
2,4,5-TP Silvex	✓	✓	✓
2,4-D	✓	✓	✓
Butachlor		✓	✓
Dalapon	✓	✓	✓
Dinoseb	✓	✓	✓
Diquat	✓	✓	✓
Pentachlorophenol	✓	✓	✓
Picloram	✓	✓	✓

PCBs/Dioxins/Furans	Baker 1999	PR DOH 1999	PR DOH 1995
PCB-1016	✓	✓	✓
PCB-1221	✓	✓	✓
PCB-1232	✓	✓	✓
PCB-1242	✓	✓	✓
PCB-1248	✓	✓	✓
PCB-1254	✓	✓	✓
PCB-1260	✓	✓	✓
Dioxin-2,3,7,7-TCDD	✓	✓	
hexa CDD	✓		
hexa CDF	✓		
penta CDD	✓		
penta CDF	✓		
tetra CDD	✓		
tetra CDF	✓		

Explosives	EPA 2000	Baker 1999	PR DOH 1999	CH2MHILL and Baker 1999
1,3-Dinotrobenzene (1,3,-DNB)	✓	✓	✓	✓
1,3,5-Trinitrobenzene (1,3,5-TNB)	✓	✓	✓	✓
2-Amino-4,6-dinitrotoluene (2,6Am-DNT)	✓	✓	✓	✓
2-Nitrotoluene (2-NT)	✓	✓	✓	✓
2,4-Dinitrotoluene (2,4-DNT)	✓	✓	✓	✓
2,4,6-Trinitrotoluene (TNT)	✓	✓	✓	✓
2,6-Dinitrotoluene (2,6-DNT)	✓	✓	✓	✓
3-Nitrotoluene (3-NT)	✓	✓	✓	✓
4-Amino-2,6-dinitrotoluene (4-Am-DNT)	✓	✓	✓	✓
4-Nitrotoluene (4-NT)	✓	✓	✓	✓
Cyclotrimethylene trinitramine (RDX)	✓	✓	✓	✓
Methyl-2,4,6-trinitrophenylnitramine (Tetryl)	✓	✓	✓	✓
Nitrobenzene (NB)	✓	✓	✓	✓
Nitrogylcerine		✓		✓
Cyclotetramethylene tetranitramine (HMX)	✓	✓	✓	✓
Pentaerythritol tetranitrate		✓		✓
Perchlorate				✓
Picric acid				✓

Radionuclides	Baker 1999	PR DOH 1999
Cesium-134		✓
Cesium-137		✓
Cobalt 60		✓
Gross Alpha	✓	✓
Gross Beta	✓	✓
Iodine 131		✓
Radium-226	✓	✓
Radium 228	✓	✓
Strontium 89		✓
Strontium 90		✓
Total Radium		✓
Tritium		✓

Miscellaneous	Baker 1999	PR DOH 1999
Asbestos		✓

APPENDIX D

Estimated Exposure and Health Effects

Estimates of Human Exposure Doses and Determination of Health Effects

Overview of ATSDR's Methodology for Evaluating Potential Public Health Hazards:

ATSDR evaluated exposures to various sources of drinking water on Vieques. To do so, ATSDR derived exposure doses and compared them against health-based guidelines. ATSDR also reviewed relevant toxicological data to obtain information about the toxicity of contaminants of interest.

Deriving Exposure Doses:

ATSDR derived exposure doses (i.e., the amount of chemical a person is exposed to over time) for all chemicals detected in drinking water sources. When estimating exposure doses, health assessors evaluate 1) contaminant concentrations to which people may have been exposed and 2) length of time and the frequency of exposure. Together, these factors influence an individual's physiological response to chemical contaminant exposure and potential outcomes. Where possible, ATSDR used site-specific information about the frequency and duration of exposures. In cases where site-specific information was not available, ATSDR applied several conservative exposure assumptions to estimate exposures for residents of Vieques.

The following equation was used to estimate exposure to contaminants in drinking water:

$$\text{Estimated exposure dose} = \frac{\text{Conc. x IR x EF x ED}}{\text{BW x AT}}$$

where:

Conc.: Maximum concentration in parts per million (ppm)
IR: Ingestion rate: adult = 3 liters per day; child = 1.5 liter per day
EF: Exposure frequency, or number of exposure events per year of exposure: 365 days/year
ED: Exposure duration, or the duration over which exposure occurs: adult = 70 years; child = 6 years
BW: Body weight: adult = 70 kg; child = 10 kg
AT: Averaging time, or the period over which cumulative exposures are averaged (6 years or 70 years x 365 days/year for noncancer effects; 70 years x 365 days/year for cancer effects)

Using Exposure Doses to Evaluate Potential Health Hazards:

ATSDR performs weight of evidence analyses to determine whether exposures might be associated with adverse health effects (noncancer and cancer). As part of this process, ATSDR examines relevant toxicologic, medical, and epidemiologic data to determine whether estimated doses are likely to result in adverse health effects. As a first step in evaluating noncancer effects, ATSDR compares estimated exposure doses to standard health guideline values, including ATSDR's minimal risk levels (MRLs) and EPA's reference doses (RfDs). The MRLs and RfDs are estimates of daily human exposure to a substance that are unlikely to result in noncancer effects over a specified duration. *Estimated exposure doses that are less than these values are not considered to be of health concern.* To be very protective of human health, MRLs and RfDs have built in "uncertainty" or "safety" factors that make them much lower than levels at which health effects have been observed. Therefore, if an exposure dose is higher than the MRL or RfD, it does not necessarily follow that adverse health effects will occur.

If health guideline values are exceeded, ATSDR examines the effect levels seen in the literature and more fully reviews exposure potential to help predict the likelihood of adverse health outcomes. ATSDR looks at human studies, when available, as well as experimental animal studies. This information is used to 1) describe the disease-causing potential of a particular contaminant and 2) compare site-specific dose estimates with doses shown to result in illness in applicable studies (known as the margin of exposure). For cancer effects, ATSDR also reviews genotoxicity studies to further understand the extent to which a contaminant might be associated with cancer outcomes. This process enables ATSDR to weigh the available evidence, in light of uncertainties, and offer perspective on the plausibility of adverse health outcomes under site-specific conditions.

For essential nutrients that do not have MRLs or RfDs (e.g., iron, magnesium, potassium, and sodium), ATSDR compares the estimated daily exposure doses to U.S. Food and Drug Administration's (FDA's) Daily Values. Because essential nutrients are important minerals that maintain basic life functions, certain doses are recommended on a daily basis.

Evaluation of Health Hazards Associated with Vieques:

Public Water Supply System:

Noncancer:

After calculating exposure doses according to the equation and assumptions described above, all chemical doses (with the exception of chloroform) were below their corresponding MRLs or RfDs. The calculated exposure dose of chloroform for a child [0.011 milligrams per kilogram per day (mg/kg/day)] only slightly exceeded EPA's chronic RfD (0.01 mg/kg/day). When compared to actual doses seen in the literature for less serious health effects (15 mg/kg/day), the calculated exposure dose is too low to be of health concern.

The calculated exposure doses for the essential nutrients that were detected in the public water—iron (0.72 mg/day for adults and 0.36 mg/day for children), magnesium (11.1 mg/day for adults and 5.5 mg/day for children), potassium (3.9 mg/day for adults and 1.95 mg/day for children), and sodium (29.7 mg/day for adults and 14.9 mg/day for children)—were well within the Daily Values recommended by FDA (iron: 18 mg/day, magnesium: 400 mg/day, potassium: 3,500 mg/day, and sodium: 2,400 mg/day). The additional intake of these chemicals from the public water supply system does not pose a health hazard to the residents of Vieques.

Cancer:

Of the chemicals detected in the public water supply system, only the disinfection byproducts (chlorodibromomethane, chloroform, and dichlorobromomethane) and di(2-ethylhexyl)phthalate are known carcinogens. Using conservative exposure assumptions, ATSDR found that the levels of these chemicals do not pose a risk for excess cancer cases in the Vieques community. ATSDR does not expect any increase in cancer risk by drinking water from the public water supply system.

Groundwater Wells:

Noncancer:

After calculating exposure doses according to the equation and assumptions described above, all chemical doses (with the exception of manganese and nitrate plus nitrite) were below their corresponding MRLs or RfDs. The exposure doses of manganese for adults (0.022 mg/kg/day) and children (0.08 mg/kg/day) slightly exceeded EPA's chronic RfD for manganese (0.02 mg/kg/day). However, when compared to actual doses seen in the literature the calculated exposure dose is too low to be of health concern. In addition, the Food and Nutrition Board of the National Research Council determined an estimated safe and adequate daily dietary intake of manganese to be 2-5 mg/day for adults (EPA 1988). Based on the highest detected concentration, daily intake from drinking water is only 1.6 mg/day for adults and 0.8 mg/day for children—well within the limit.

The exposure doses for nitrate plus nitrite (0.54 mg/kg/day for adults and 1.89 mg/kg/day for children) were above EPA's chronic RfD for nitrite (0.1 mg/kg/day) and for nitrate (1.6 mg/kg/day). In addition, the chemical concentration detected in Well 3–7 (12,600 ppb) was higher than the maximum contaminant level (MCL: 10,000 ppb) set by EPA. Because of the elevated nitrate plus nitrite levels detected in the water from Well 3–7, a potential public health hazard may exist if residents drink water from this well. Puerto Rico Department of Health has issued an advisory for Well 3–7 and informed residents not to drink water from this well.

The calculated exposure doses for the essential nutrients that were detected in the groundwater wells—iron (6.5 mg/day for adults and 3.2 mg/day for children) and sodium (687 mg/day for adults and 344 mg/day for children)—were below the Daily Values recommended by FDA (iron: 18 mg/day and sodium: 2,400 mg/day). The additional iron that would be received by drinking water from the Sun Bay wells is not harmful. The additional sodium could be of a health concern for those individuals with sodium-restricted diets. Determining whether the additional sodium intake will adversely affect a person's health is an individual assessment based on that person's diet and health status.

In order to determine if the limits of detection for explosives were protective of public health, ATSDR calculated exposure doses using the limits of detection as the maximum concentration in the formula described above. All of the calculated doses were at levels too low to be of health concern (i.e., below their respective MRLs and RfDs) for both noncancerous and cancerous health effects.

<u>Cancer:</u>

Of the chemicals detected in groundwater wells, only chloroform and di(2-ethylhexyl)phthalate are known carcinogens. Using conservative exposure assumptions, ATSDR found that the levels of these chemicals do not pose a risk for excess cancer cases in the Vieques community. ATSDR conservatively assumed that people were exposed to the maximum detected concentration on a daily basis over a lifetime exposure, even though samples collected at other times contained lower levels. ATSDR does not expect any increase in cancer risk by drinking water from groundwater wells.

Historical Drinking Water Samples:

<u>Noncancer:</u>

All of the calculated exposure doses for chemicals (with the exception of nitrate plus nitrite) detected in historical drinking water samples were well below their corresponding RfDs or MRLs. The exposure doses for nitrate plus nitrite (0.21 mg/kg/day for adults and 0.77 mg/kg/day for children) were above EPA's chronic RfD for nitrite (0.1 mg/kg/day), but below the RfD for nitrate (1.6 mg/kg/day). There is not an MRL or RfD for nitrate plus nitrite. Because the sample was analyzed for nitrates and nitrites together, it is impossible to determine how much of the sample is actually nitrate and how much is nitrite. However, it is highly unlikely that the entire sample is nitrite. In addition, the actual detected concentration (5,100 ppb) was almost half of EPA's MCL (10,000 ppb) for nitrate plus nitrite. For these reasons, ATSDR determined that exposure to the chemicals detected in the historical drinking water samples did not pose a health hazard to the residents of Vieques.

<u>Cancer:</u>

Of the chemicals detected in historical drinking water samples, only cyclotrimethylene trinitramine (RDX) and dinitrotoluene are carcinogenic. Using conservative exposure assumptions, ATSDR found that the levels of RDX and dinitrotoluenes assumed to be in the drinking water samples did not pose a risk for excess cancer cases in the Vieques community. ATSDR conservatively assumed that people were exposed to the maximum detected concentration on a daily basis over a lifetime exposure, even though current samples did not detect RDX or dinitrotoluenes. ATSDR does not expect any increase in cancer risk for people who drank water from the locations where the historical sample were taken.

APPENDIX E

Naval Surface Weapons Center Water Sampling, 1978

Naval Surface Weapons Center Water Sampling, 1978

The Navy reported very low levels of cyclotrimethylene trinitramine (RDX) and methyl-2,4,6-trinitrophenylnitramine (tetryl) in water samples from Vieques in 1978 (Lai 1978, Hoffsommer and Glover 1978). ATSDR reviewed that data, as well as the sampling and analytical procedures, to evaluate whether those reported detections posed a potential health hazard.

ATSDR concludes that even though there is uncertainty about the source of the water sampled, RDX and tetryl may have been detected in very low concentrations in areas outside the LIA. These chemicals were at levels below health concern and did not pose a health hazard to residents who may have ingested these chemicals in drinking water. It should also be noted that, given the uncertainties stated by the laboratory that analyzed the samples, the interpretation that these chemicals were present in the water source at the reported levels is a conservative interpretation used to be protective of human health; it should not be interpreted as validation of the laboratory study's results.

Historical Drinking Water Supplies:

Discussion:

There were various potential sources of drinking water for residents of Vieques in 1978. The pipeline from the main island of Puerto Rico began operation in 1977, supplying public drinking water by 1978. Drinking water wells in the Esperanza aquifer that had previously been the supply of public drinking water were not closed until some time in 1978. Additionally, rainfall collection systems were still used by individuals. Although water from these collection systems did not enter the public water supply system, storage tanks at homes or at businesses may have been filled by either public water or rainfall as needed.

Sampling Summary:

In 1978, the Naval Surface Weapons Center obtained and analyzed water samples inside and outside the LIA on Vieques at the request of the Chief of Naval Operations. The samples were collected one week after a military exercise in which live ordinance was used at the LIA. Fifteen water samples were taken within the LIA and 11 water samples were taken outside the impact area. Only four of these samples represent drinking water. Fourteen samples were taken of seawater and water in lagoons around the island. Eight samples were taken from bomb craters or runoff from craters (Lai 1978, Hoffsommer and Glover 1978). This discussion focuses on the drinking water samples.

Although the location of each sample is noted in the Navy report, the source of the water sampled is not documented. As previously discussed, drinking water on the island may have been piped in from Puerto Rico, collected as rainfall, pumped from the ground, or a combination of these sources. Two of the drinking water samples were taken from public water storage tanks (storing water piped in from the main island of Puerto Rico)—one sample each from Esperanza and Isabel Segunda (Lai 1978, Hoffsommer and Glover 1978). However, the water sample from Isabel Segunda was reported to be "diluted with rainfall" (Lai 1978). Although this note is not explained further, it is possible that the Isabel Segunda sample was taken from a storage tank that received both public water and rainwater from a rainfall catchment system. Note that an environmental consultant hired by the Government of Puerto Rico reported that air could be pulled into the public water storage tanks through the air vents (EPA 1999a). A third sample, from the pump house in the NASD area, is also believed to be drinking water. The source water for this sample was not noted, but since it is a pump house, the source may be a groundwater well in the Resolution aquifer (possibly Navy Well 17). The fourth drinking water sample is listed as site "OP–1", drinking water from Cerro Matias, but no source is given. OP–1 is the observation tower and the closest drinking water sample to the LIA. This sample may include rainfall collection or possibly water trucked in from Camp Garcia; there is no groundwater well near the observation tower.

The samples were tested for explosives (2,4,6-trinitrotoluene (TNT), RDX, and tetryl) [Hoffsommer and Glover 1978] and for explosion combustion products (i.e., compounds that are formed after bombs detonate: ammonia, cyanide, nitrate plus nitrite, perchlorate, and phosphorous) [Lai 1978]. Sample OP–1 was not tested for explosion combustion products.

The Navy laboratory that analyzed the samples had developed very sensitive techniques for detecting explosive compounds in order to test for explosives in seawater (Hoffsommer and Rosen 1972). These methods were more sensitive than the current EPA laboratory methods that are now considered the standard for environmental work. The detection limits are reported by the laboratory that performs the analysis and may change slightly with each analysis. Although the Navy laboratory reported very low detection limits, the authors note that "a completely positive identification was not possible due to the extremely low concentrations found" (Hoffsommer and Glover 1978). They further note "if these explosives are present, the concentrations do not exceed the values reported here."

Compounds that might interfere with the analysis are those that might leach from plastic or rubber materials (Hoffsommer and Rosen 1972). Two of the non-drinking water samples contained interfering peaks. They were re-analyzed with a slightly different method to compensate for the interference (Hoffsommer and Glover 1978). Lai notes that samples used in testing for explosion combustion products were collected with a polyethylene bottle. It is unknown if this collection method was also used for samples collected for explosives analysis. However, it is believed that both sets of samples were collected together by the same personnel.

Despite some of the uncertainties in the source of water sampled (and therefore its representativeness for exposures from drinking water), the potential health effects of the detected chemicals are evaluated here as if they were representative of a drinking water source on the island. It should also be noted that, given the uncertainties stated by the laboratory that analyzed the samples, the interpretation that these chemicals were present in the water source at the reported levels is a conservative interpretation used to be protective of human health; it should not be interpreted as validation of the laboratory study's results.

Water Quality:

TNT was not detected in any of the drinking water samples (Table E-1). However, it is unclear from the report if TNT degradation products, specifically 4-amino-2,6-dinitrotoluene (4-A-DNT) and 2-amino-4,6-dinitrotoluene (2-A-DNT) were detected in any of the drinking water samples (Hoffsommer and Glover 1978). The authors give a detection range of 0.1 to 0.01 ppb of 2-A-DNT in all samples where the chemical was present but do not indicate which samples contained the 2-A-DNT. Since the authors are discussing all samples, including water samples from the LIA and adjacent seawater samples, it is unknown if any drinking water samples contained the 2-A-DNT. 4-A-DNT was not measured directly, but was considered by Hoffsommer and Glover (1978) to be present at the same levels as 2-A-DNT, where present.

The water sample from OP–1, the sample location closest to the LIA, did not contain measurable amounts of explosive products. However, drinking water from Esperanza was reported to have RDX (0.04 ppb) and drinking water from Isabel Segunda was reported to have both RDX and Tetryl (0.04 ppb and 0.5 ppb, respectively). The water from the Navy pump house in the magazine area on the west end of the island contained 0.06 ppb RDX (Hoffsommer and Glover 1978) [Table 6]. It should be noted that RDX was not distinguishable from 4-A-DNT in this study, so positive identification of this chemical was not possible. However, since the authors were aware of this fact and reported these results as RDX, it was evaluated as such.

Only two of the possible explosion combustion products were detected in drinking water sources—ammonia and nitrate plus nitrite. Ammonia was detected at the pump house at a concentration of 20 ppb. The drinking water samples from Esperanza, Isabel Segunda, and the pump house contained 4,900 ppb, 240 ppb, and 5,100 ppb of nitrate plus nitrite, respectively (Table 6). Additionally, water samples taken directly from bomb craters on the LIA had nitrate plus nitrite from only 1,700 ppb to 2,500 ppb (Lai 1978). The levels of nitrate plus nitrite in the Esperanza and Navy pump house water samples are consistent with groundwater on the island and are not a conclusive indication of explosive byproducts.

> Ammonia and nitrate plus nitrite are commonly detected in drinking water samples. These chemicals could result from a number of sources and do not necessarily indicate the presence of bombing-related chemicals.

Evaluation of the Impact of Water Quality on Public Health:

The concentrations of the explosive compounds (RDX and tetryl) that were detected in drinking water are not at levels of health concern. Daily intake rates that were calculated based on drinking 3 liters of water a day (1.5 liters for a 10 kg child) show doses at least 3 orders of magnitude below a level of health concern (0.003 mg/kg/day for RDX and 0.01 mg/kg/day for tetryl) for noncarcinogenic effects. Similarly, the potential for the TNT breakdown products, 4-A-DNT and 2-A-DNT, would not pose a hazard, even with calculating doses on the assumption that both compounds are present at the maximum detected value—in water from the LIA. A lifetime exposure to these levels in drinking water does not pose a cancer risk for RDX and the dinitrotoluenes, compounds which are possible human carcinogens. The carcinogenic potential of tetryl cannot be assessed because of lack of experimental data. Please refer to Appendix D for further details concerning how ATSDR estimated exposure doses and determined health effects.

The level of ammonia and nitrate plus nitrite detected is similar to what was found in groundwater sources previously discussed. Use of this water, even over a lifetime, does not pose health hazards from exposure to these chemicals.

Table E-1. Chemicals Detected in Historical Drinking Water Samples

Chemical	Chemical Concentration (ppb)				Drinking Water Standards (ppb)
	NASD (pump house)	Esperanza (public water)	Isabel Segunda (public water)	Cerro Matias (OP-1)	
Explosives					
TNT	ND	ND	ND	ND	ND
RDX	0.06	0.04	0.04	ND	NA
Tetryl	ND	ND	0.5	ND	NA
Explosion Combustion Products					
Ammonia	20	ND	ND	NS	NA
Cyanide	ND	ND	ND	NS	ND
Nitrate plus nitrite	5,100	4,900	240	NS	10,000†
Perchlorate	ND	ND	ND	NS	ND
Phosphorous	ND	ND	ND	NS	ND

Reference: Hoffsommer and Glover 1978; Lai 1978

Abbreviations:
MCL = Maximum Contaminant Level (EPA)
NA = Not Available
ND = Not Detected
ppb = parts per billion
†MCL

APPENDIX F

Responses to Public Comments

Responses to Public Comments

The Agency for Toxic Substances and Disease Registry (ATSDR) received the following comments during the public comment period (February 20 to May 4, 2001) for the Petitioned Isla de Vieques (Vieques) Public Health Assessment (PHA) (February 2001). For comments that questioned the validity of statements made in the PHA, ATSDR verified or corrected the statements. The list of comments does not include editorial comments concerning such things as word spelling or sentence syntax.

Pathways Other Than Consumption of Contaminated Water

1. **Comment:** *Three commentators note that the PHA did not evaluate all the potential exposure pathways that they were concerned about, such as the inhalation of contaminated air and dust, the consumption of contaminated foods, and the drinking of contaminated rainwater. One of these commentators argues that the PHA's analysis of drinking waters is incomplete because it does not consider the effects of air and dust pollution on the waters.*

   Response: The public health assessment process may be lengthy, especially when addressing complex environmental issues. To be most responsive to the petitioner and the people of Vieques, ATSDR is addressing each exposure pathway in a different document, called a focused public health assessment. Each focused PHA examines environmental exposure through a different media (e.g., water, air, soil, and food chain). This focused PHA only addresses the public health implications of exposure through drinking water from public and private groundwater wells and the public water supply system. Within the PHA, ATSDR acknowledges that we cannot address public health issues pertaining to drinking water from rainfall catchment basins because no sampling or use data currently exist.

   ATSDR is preparing a focused PHA pertaining to inhalation of air and dust and focused PHAs on soil and consumption of fish and shellfish.

   Within the Pathway Analysis section of the PHA, ATSDR explains that hydrogeologically there is no connection between groundwater at the Live Impact Area (LIA) and groundwater of the central portion of Vieques; therefore, the only way that groundwater in the residential section of the island could be impacted by operations at the LIA is "through air transport, deposition, and later movement of contaminants through the soil into the underground aquifers." Further, ATSDR recognizes that until the air pathway evaluation is completed, we do not know if "any measurable amount of chemical residue has traveled through the air to these areas." Despite not having the results of the air evaluation, this PHA's evaluation is still complete because ATSDR based the public health conclusions on data from the point of exposure (i.e., drinking water), which would be the same regardless of the source of the contamination.

2. **Comment:** *One commentator suggests that ATSDR investigate potential exposure pathways involving consumption of waterfowl, shellfish, and land crabs. The commentator notes that no data on contaminant levels in these organisms currently exist.*

   Response: In July 2001, Environmental Response Team (ERT), a division of the U.S. Environmental Protection Agency (EPA), in cooperation with ATSDR sampled fish and shellfish from the coastal waters surrounding Vieques and land crabs from the LIA. ATSDR will evaluate the data once it becomes available and anticipates releasing a focused PHA addressing the consumption of fish and shellfish.

3. **Comment:** *Two commentators register their concern about airborne pollution resulting from Naval operations at the LIA. They are concerned about the chemicals contained in explosives, the chemicals generated by explosions, and the rock and pulverized metal dust kicked into the air after an explosion. The commentators note that prevailing winds generally blow from east to west and are concerned about the transport of airborne pollutants from the LIA to settled areas west of there. One commentator notes that many of the particles generated at the LIA may be so small they would travel a long distance before settling to the ground. The other commentator is also concerned that these dusts might transport heavy metals, radioactive materials, and organic compounds as they travel.*

   Response: ATSDR is aware of the prevailing wind pattern that could blow airborne contaminants from the LIA to the residential area of the island. This specific concern will be evaluated in the focused PHA that addresses air contamination.

4. **Comment:** *One commentator suggests that ATSDR has been credulous in accepting that African dust storms are a significant source of dust in Vieques. The commentator explains ATSDR's willingness to believe this theory with the assertion that ATSDR holds preconceived ideas about the public health risks of Navy operations at Vieques.*

   Response: Credible research conducted by the U.S. Geological Survey (USGS) and others, supports the validity of the African dust phenomenon. ATSDR is in the process of conducting a systematic evaluation of the potential pathways of human exposure to contaminants that may have been released during, or as a result of Navy training activities on Vieques. Our objective public health evaluations will be based upon the findings of those studies.

5. **Comment:** *One commentator expresses displeasure that ATSDR's Public Health Action Plan contains no reference to noise pollution. The commentator asserts that this issue is within ATSDR's purview and demands that the Agency either conduct a study of the effects of noise pollution on Vieques or state its reasons for declining to do so.*

   Response: ATSDR is researching whether noises from the Navy bombing exercises cause the outer lining of the heart tissue among Vieques fishermen to thicken, as reported by a recent study (Torres et al.). In July 2001, ATSDR, the Ponce School of Medicine, and the Centers for Disease Control and Prevention co-sponsored an expert panel to review a study conducted by the Ponce School of Medicine. The findings of the review panel will be published separately.

6. **Comment:** *One commentator notes that the sediments at the Cerro Matías shooting range and other similar Navy sites are extremely sensitive to erosion. The commentator explains that these sediments are only sparsely covered by vegetation and are readily pulverized by the detonation of explosives and other human activities there. Once disturbed, these sediments may be easily transported from place to place. The commentator suggests that contaminated sediments might move in such a fashion as to concentrate contaminants in local areas.*

   Response: ATSDR realizes that sediments from the LIA may be transported through the air or wash into the ocean. The transportation of sediments from the LIA through the air will be addressed in the focused PHA concerning the air pathway. The issue of sediments carrying contaminants into the ocean will be indirectly addressed in the focused PHA concerning fish and shellfish consumption in so far as it is one of the possible ways the marine biota could be impacted by the bombing activities at the LIA.

   Any movement of sediments at the LIA is not expected to directly impact the groundwater quality in residential areas because the geology and topography of the island prevents groundwater from moving in that direction. Indirectly, the groundwater could be influenced by aerial deposition of sediments from the LIA, however sampling indicates that the water is not contaminated to levels of health concern, with the exception of nitrate plus nitrite levels in Well 3-7. Additionally, recent groundwater sampling did not detect explosives or their residues in any groundwater on the island.

   Please read the response to the next comment for an answer concerning the possibility of sediment being transported *via* sea water.

Possible Routes of Water Contamination Not Adequately Examined

7. **Comment:** *One commentator asserts that past studies of marine biota demonstrate that the sea waters surrounding the LIA have been contaminated with heavy metals from the Navy's operations. The commentator suggests that pollutants may be transported from the LIA to Vieques' alluvial groundwater supplies via the movement of contaminated sea water.*

   Response: There is no evidence that this route of movement would contribute substantially to the contaminant levels in the alluvial aquifers. First, any metals that wash into the ocean from the LIA would be greatly diluted in the ocean and second, they would have to travel a very specific route to reach the alluvial aquifers. Even if some of the metals reached the alluvial aquifer, it would be highly unexpected that the saltwater which contains the metals would mix with the fresh water that is being used because of the difference in densities between the two media. ATSDR is evaluating potential bioaccumulation of metals in marine biota.

8. **Comment:** *Two commentators suggest that ATSDR has not adequately addressed the possibility that water supplies in Vieques have been contaminated by dusts blown from the LIA. One commentator cites a 1978 study performed by the Navy. This study is asserted to reveal the presence of explosive residues in drinking water tanks holding water piped from mainland Puerto Rico.*

   Response: ATSDR acknowledges in the Pathway Analysis section of the PHA that groundwater in the residential section of the island could be impacted by operations at the LIA "through air transport, deposition, and later movement of contaminants through the soil into the underground aquifers." By evaluating the available sampling data (i.e., the point of exposure), ATSDR was able to conclude whether drinking the water was of health concern, regardless of how the chemicals got there. The public water supply tanks do no have contaminant levels of health concern.

   ATSDR addressed the findings of the 1978 study performed by the Navy (Hoffsommer and Glover 1978; Lai 1978) in Appendix E of the PHA. Please read Appendix E for details pertaining to ATSDR's conclusions from this report.

9. **Comment:** *Three commentators urge ATSDR to evaluate the public health risks involved in consuming drinking water collected from rainfall. One commentator contends that ATSDR is unaware of how contaminated this water might be and how many rainfall collection systems are in use. Therefore, the commentator concludes, the PHA's statements reassurances that drinking water on Vieques is safe are inadequately grounded. Another commentator suggests that the connection between contaminant level*

in rainwater and the use of ammunition on the LIA be "recreated." for the sake of reconstructing past exposures.

Response: ATSDR acknowledges in Question 3 of the Evaluation of the Drinking Water Quality section of the PHA that we are unable to evaluate the public health risks involved in drinking water from rainfall catchment basins due to the lack of use and sampling data. ATSDR recommends in the Public Health Action Plan that the Puerto Rico Department of Health (PRDOH) or the Puerto Rico Environmental Quality Board (PREQB) identify where collection systems are being used and perform sampling to evaluate if these systems deliver tap water that is safe to drink. Further, if the storage tanks associated with these collection systems contain bottom sediments, it is recommended that those sediments be sampled to provide an indication of potential past water quality.

The potential for contaminants from the LIA to travel through the air and be deposited in rain water catchment systems is being assessed and will be discussed in the focused air pathway document.

10. **Comment:** *Two commentators criticized the PHA for failing to take into consideration potential sources of water pollution from the Naval Ammunition Support Division (NASD) at the western end of Vieques. One commentator expressed particular frustration that this land has been transferred to Vieques Municipality subject to the restriction that no wells (including monitoring wells) may be established upon it. The commentator asserts that ammunition was burned and exploded on the NASD and cites a study performed by CH2MHILL as evidence that regions of the NASD are polluted above federal standards. The commentator acknowledges that CH2MHILL dismissed its findings for being below background levels for Vieques, but draws ATSDR's attention to the fact that CH2MHILL now admits that those background levels may need to be reevaluated. The commentator recognizes that ATSDR made a deliberate, disclaimed decision to confine the PHA to a discussion of potential contamination from the LIA and thus to exclude the NASD from consideration. At the same time, however, the commentator states that ATSDR draws overly general conclusions about the safety of Vieques' drinking water from this restricted report.*

    Response: ATSDR did review contaminant data collected on the former NASD. There is no evidence that the localized groundwater contaminants of that area have, or can migrate to areas of potential human exposure.

11. **Comment:** *One commentator criticized the PHA for failing to take into consideration potential sources of water pollution from the Atlantic Fleet Weapons Training Facility (AFWTF).*

Response: The LIA is part of AFWTF. As with the LIA there is also no hydrogeologic connectivity between the alluvial aquifers on AFWTF and those on the residential section of the island. Groundwater at AFWTF does not migrate to the west towards aquifers in the residential area for the same hydrogeologic and topographic reasons that the groundwater cannot move from the LIA towards the west. Groundwater at AFWTF, like the LIA, flows downhill north and south into the ocean or into isolated alluvial aquifers near Ensenada Honda.

Several groundwater monitoring wells were drilled in the EMA near the residential area. Analyses of samples collected from those wells did not detect the presence of contaminants.

12. **Comment:** *One commentator criticized the PHA for failing to take into consideration potential sources of water pollution from the Eastern Maneuver Area (EMA), which is closer to populated areas of Vieques than the LIA. The commentator asserts that ammunition was stored and discharged there and that Agent Orange was used there as part of training exercises.*

    Response: Potential sources of contamination from the EMA were considered for their influence on the nearby aquifers. The only drinking water source (former) in the EMA is the Navy Well 14. Two monitoring wells are also located in the EMA alluvial deposits. These three wells were tested for components of Agent Orange (2,4,5-T and 2,4-D, see Herbicides in Appendix C). No detections were found (see Table 3). These negative findings and the hydrogeology of the area which shows that groundwater does not flow in the direction of the communities indicate that groundwater wells are safe drinking water sources with respect to potential past use of the EMA for Agent Orange.

Contaminants of Concern

13. **Comment:** *One commentator argues that since most of the bombs used by the Navy were non-explosive, ATSDR should concentrate more on looking for residues of rocket fuels and propellants. In particular, the commentator suggests that further testing be done for ammonium perchlorate. The commentator notes that only one of the four sets of laboratory tests cited in Appendix C of the PHA checked for this chemical.*

    Response: Rockets are designed to burn the propellants they contain, leaving very trace amounts of residual chemicals. Therefore, it is not expected that propellant residues would accumulate in large amounts. The Navy provided compositional information on the two kinds of rockets that are used on Vieques. The propellants mainly contain nitrocellulose and nitroglycerin (89.6% and 87.24% combined). Ammonium perchlorate is used in air to surface rockets.

- Nitrocellulose was not sampled in any of the water wells or tanks. However, it is not a chemical expected to cause harmful health effects if found in the water because the available studies indicate that ingestion of nitrocellulose does not result in adverse health effects unless ingested in enormous quantities (e.g., ingestion of 10% nitrocellulose of the total diet caused animals to die from intestinal obstruction; EPA 1992).

- In August 1999, nitroglycerin was sampled in water from 11 monitoring wells along EMA's western border, a former drinking water well in Camp Garcia (Navy Well 14), a former supply well in the NASD (Navy Well 17), and the NASD tank. It was never detected.

- Ammonium perchlorate has been detected (at 0.123 ppb) in only one of 37 surface soil samples on or near the on the LIA in the soils. It is not known, but is not likely that ammonium perchlorate is in the groundwater directly below the LIA. It was, as noted by the commentator, tested for in one of the rounds of groundwater testing. It was not detected in any of the wells in the EMA. In addition, as stated before, groundwater does not flow from the LIA or EMA to groundwater wells in the communities.

14. **Comment:** *One commentator faults ATSDR for failing to furnish a complete list of the chemicals used for Naval ammunition at Vieques. Furnishing an example of a substance that ATSDR has not taken into consideration, the commentator asserts that in 1992 the Navy used napalm at Vieques. The commentator presses ATSDR to either provide a new list of chemicals that can be certified as complete or clearly state that it was unable to generate a complete list of the chemicals used as ammunition at Vieques.*

    Response: Several factors were taken into consideration in assessing the drinking water issues on Vieques. The multitude of individual chemicals of various chemical classes (see Appendix C) for which water samples were tested and the low levels and low numbers of detections that were found show that excessive contamination has not reached the groundwater (see Tables 4 and 5). The explosive compounds tested for cover a large range of munition types. ATSDR considers the list of explosive compounds that were used for the majority of training exercises to be adequate for assessing the groundwater issues at Vieques.

    ATSDR is aware of napalm use on the LIA in 1992. Napalm is basically a mixture of gelled gasoline that burns and leaves little specifically traceable residue. One group of residues that might be left by the burning of napalm are polynuclear aromatic hydrocarbons (PAHs), which are listed under Semi-volatile Organic Compounds in Appendix C. The presence of PAHs could be from many sources, including a residue of burned napalm; however, PAHs were not detected in any of the groundwater supplies tested.

Multiple Chemical/Multiple Pathway Exposure

15. **Comment:** *Two commentators criticize ATSDR's practice of separately analyzing human health risks from different exposure pathways. The commentators are concerned about an imagined scenario in which ATSDR would find that human exposures to a particular chemical were within safe levels for individual pathways but would fail to notice that combined exposure from all pathways exceeded safe levels.*

    Response: The entire public health assessment process is lengthy, especially when addressing complex environmental issues. ATSDR is evaluating each exposure pathway separately to be most responsive to the petitioner and the people of Vieques.

    After all the individual focused PHAs are completed, ATSDR will prepare a short summary of all health issues we have evaluated at Vieques. This summary will consider whether overall exposures to environmental contaminants pose a public health hazard, rather than focusing on exposures through just one medium.

16. **Comment:** *Two commentators are concerned that ATSDR would not take into account the combined or even synergistic effects of different chemicals that residents of Vieques might be exposed to. The commentators are concerned about an imagined scenario in which ATSDR would find that human exposures to individual chemicals were all within the safe levels established for those chemicals but would fail to notice that the additive or synergistic effect of all those chemicals was hazardous.*

    Response: Most of the literature on the effects of mixtures focuses on relatively HIGH exposures that may produce results such as synergism and non-competitive inhibition. However, concentrations far in excess of typical environmental concentrations are generally required to produce such effects.

    Several studies conducted under the auspices of the National Toxicology Program (NTP) in the U.S. and the TNO Nutrition and Food Research Institute in the Netherlands, among others (For reviews, see Seed et al. 1995; Feron et al. 1993.) generally support the conclusion that exposure to a mixture of chemicals is unlikely to produce any adverse health effects as long as the components of that mixture are present at levels well below their respective No-Observed-Adverse-Effect-Levels (NOAELs; i.e., at concentrations that would have produced no adverse effects in animals separately treated with the component chemicals individually). This observation appears to hold whether the component chemicals affect the same or different target organ(s) via different mechanisms (i.e., the situations that generally pertain to typical environmental mixtures). Even chemicals with the same or similar modes of action apparently exhibit neither synergism nor additivity, as long as the levels of exposure are well below the respective NOAELs of the component chemicals. This scenario fits the levels of chemicals found in drinking water and groundwater on Vieques.

Sampling Issues

17. **Comment:** *Five commentators expressed the opinion that ATSDR is remiss in failing to generate its own data to supplement those which it collected from published sources. One commentator suggested that ATSDR should have sampled water from the actual wells that are used in emergency circumstances. Another commentator suggested that ATSDR has unduly restricted the scope of its data selection process and argued that it must supplement its research with additional new data in order to construct meaningful conclusions. One of these commentators acknowledged that this state of affairs is not the result of any conscious decision by ATSDR officials, but rather of their lack of power and legislative authority.*

    Response: ATSDR reviews all existing environmental data and exposure information that is available when drawing its conclusions and making its recommendations about public health. ATSDR considers the quality and extent of the existing information about the groundwater, the public drinking water system, and the hydrogeological findings, to be sufficient to support the public health decisions discussed in the document.

18. **Comment:** *Two commentators scoffed at ATSDR's request that the Navy conduct soil sampling for a future evaluation air exposure pathways. One commentator assured ATSDR that the people of Vieques will not trust data generated under the Navy's auspices. Another wonders why ATSDR didn't chose a neutral party to conduct the sampling.*

    Response: ATSDR requested that the Navy sample soil on the LIA to aid in the air exposure pathway evaluation because it is the Navy's land and responsibility, the Navy is most equipped to safely obtain samples considering the safety issues of unexploded ordnance, and the time frame between training exercises was short. ATSDR was fully involved in designing the sampling plan. The sampling plan was designed using the number of samples, sample locations, and types of chemical analyses that ATSDR requested.

19. **Comment:** *Two commentators criticized ATSDR for failing to cite environmental research conducted by certain Puerto Rican researchers. One commentator suggested that ATSDR invite Puerto Rican scientists to assist in developing the PHAs.*

Response: ATSDR makes every attempt to evaluate relevant environmental research whenever possible. Much of the data evaluated in this document was provided by Puerto Rican agencies including PRDOH and PREQB. We have requested reports, documents and other relevant information from many sources. ATSDR spent several days in Puerto Rican libraries to obtain the most relevant reports that may not have been in general circulation.

Explosives

20. **Comment:** *One commentator asserted that the groundwater around Vieques has never had an adequate test for explosives. The commentator was perplexed that one of the PHA's "actions planned" is to sample the Sun Bay wells before these wells are used in an emergency. The commentator reminded ATSDR that an emergency could necessitate the immediate use of these wells at any time—there would be no time for the sampling that ATSDR recommends. If one admits that the wells should be sampled before use, and one recognizes that the wells could be required at any moment, one is driven to the conclusion that they should be sampled immediately, not in the indefinite future.*

    Response: After evaluating specific drinking water data as well as data from nearby monitoring wells, ATSDR believes that the emergency wells are safe for use in the case of emergencies. Many issues must be considered when a closed well is used for emergency supply. Wells that are not routinely used should be pumped out before water is used. Appropriate local authorities should be involved before emergency supplies are used. In addition, since time has passed from the last testing, ATSDR feels that a prudent public health action would be to evaluate the wells for water quality before use. As an advisory agency, ATSDR works with and provides recommendations to other responsible parties or agencies to ensure that measures protective of public health, such as testing, are taken. However, because ATSDR works in a non-regulatory capacity, we lack the authority to enforce these actions.

21. **Comment:** *One commentator inquired after the specific standards that were used for explosives. The commentator also noted that although EPA has standards for several explosives, it does not have an approved laboratory method for sampling.*

    Response: The health guidance values (i.e., standards) used to compare calculated doses are ATSDR's minimal risk levels and EPA Region III's Reference Doses. EPA Region III's cancer slope factors were used to estimate whether carcinogenic explosives were detected at levels of health concern.

Explosive compounds were analyzed by an EPA contract laboratory using SW-846, method 8330 "Nitroaromatics and Nitroamines by High Performance Liquid Chromatography." This method is approved under EPA's Hazardous Waste Program in the Office of Solid Waste.

22. **Comment:** *One commentator inquired after the results of PRDOH's 1999 sampling for explosives and asked if explosives had ever been detected since 1978.*

    Response: In June 1999, PRDOH sampled for explosives in four public water supply tanks and one tap connected to the public water supply (PRDOH 1999). All of the results were below detection limits. Explosives have not been detected in any of the water samples taken since 1978.

23. **Comment:** *One commentator wondered about the objectives of the agencies conducting the various tests and whether they were consistent with each other.*

    Response: The following describes the various objectives of the agencies who conducted sampling on Vieques, if the objectives were stated in the referenced reports:

    - In 1995, PRDOH conducted groundwater sampling at the Sun Bay wells and B wells (PRDOH 1995a, 1995b). No objectives for this sampling are noted.
    - USGS sampled five wells in the NASD during rehabilitation activities in 1996, to acquire a representative groundwater sample of the Resolucion aquifer (USGS 1997).
    - PRDOH sampled for explosive residues in supply and distribution tanks and a local tap in 1999 because they were aware of a study by Rafael Cruz Perez, *Contamination Produced by Explosions and Explosive Residues in Vieques, Puerto Rico*, that mentioned the possibility of explosive contamination and knew that explosive residues were not regulated in potable water (PRDOH 1999).
    - The Navy's contractor installed and sampled monitoring wells along EMA's western boundary in 1999, to determine if the groundwater contains explosive compounds, assess if there is a potential for the compounds to migrate off-site, evaluate the groundwater flow direction in this area, and assess the risk posed to potential receptors if explosives were found (CH2MHILL and Baker 1999).
    - In 1999, EPA and the Navy's contractor performed split sampling at the NASD distribution tank, a former supply well in the NASD, and a former drinking water

well in Camp Garcia as part of the groundwater sampling efforts (Baker 1999). No objectives for this sampling are noted.

- EPA sampled potable water supply and distribution tanks, the Sun Bay wells, and private and public wells in 1999, to determine the overall quality of the water and the level of certain contaminants because various parties raised concerns that explosive residuals were potentially contaminating the water supply (EPA 1999b). They re-sampled in 2000, because the explosives data from the 1999 sampling was determined by EPA to be unusable (EPA 2000).

Although the various sets of data may have been collected by the individual agencies with slightly different objectives in mind, the overall data set provides appropriate information for ATSDR's public health evaluation.

Water Use

24. **Comment:** *One commentator noted that the Water Authority of Puerto Rico plans to construct a reservoir from the mainland river that supplies Vieques' water. This improvement would improve the piped water supply on Vieques and ensure that well water would only be needed during severe drought or emergencies.*

    Response: Thank you for the information. ATSDR understands that the reliability of the public water supply is of concern to the residents of Vieques. This advancement should greatly improve the dependability of the public water system.

25. **Comment:** *One commentator noted that he never saw a rainfall collection system in use. He also notes that between 1965 and 1967, most potable water in Camp Garcia came from the NASD on the west end of the island.*

    Response: Thank you for the information.

26. **Comment:** *One commentator warned that if the water supply from Puerto Rico were disrupted, the water in the transmission pipe would be exhausted in about 5 days and it could take months more to restore water flow.*

    Response: Compania de Aquas, a company hired by the Puerto Rico Aqueduct and Sewer Authority (PRASA) to maintain and operate the pubic water supply system, is responsible for distributing drinking water to the residents of Vieques. Any concerns surrounding the operation of the public water supply system should be brought to their attention.

Sun Bay Wells

27. **Comment:** *Two commentators denied that ATSDR has addressed the concern of the original petitioner, Gordon Rumore Ferris, that the wells in the Sun Bay area may be contaminated. Both commentators insisted that the only acceptable way to address this question is to directly measure the quality of the water in those wells. They furthermore noted that no reliable sampling for explosive residues has taken place at these wells. They argue that for public health purposes, it is unacceptable to rely on conclusions about these wells that were made indirectly—that is, by extrapolating from observations made elsewhere. One commentator urged ATSDR to retract its statement that the wells do not pose a health hazard and arrange to have the Sun Bay wells tested immediately for explosive contamination.*

    Response: The Sun Bay wells have been extensively sampled by PRDOH and EPA. In May 1995, PRDOH directly measured the quality of the water for inorganics, metals, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides, herbicides, and polychlorinated biphenyls (PCBs) [PRDOH 1995a]. In addition, EPA tested water from the Sun Bay wells in September 1999, for inorganics, metals, VOCs, SVOCs, and explosive residues; however, the explosives data were later determined by EPA to be unusable[1] (EPA 1999b). When EPA returned to Vieques in January 2000 to re-sample the Sun Bay wells for explosive residues, they were unable to "because they had been closed by PRASA" (EPA 2000). None of the chemicals reported to be present in the Sun Bay wells were detected at levels of health concern.

    Despite the lack of valid explosive residue data for the Sun Bay wells, ATSDR can make justifiable health decisions concerning the use of the Sun Bay wells in the event of an emergency. ATSDR does not expect explosive compounds to be detected at levels of health concern in the Sun Bay wells for the following reasons:

    - Explosives are designed to be consumed by the explosion and; therefore, are not expected to be released in large quantities.
    - There is no hydrogeologic connectivity between the Sun Bay wells and the groundwater at the LIA.
    - The sampling data establishes that there is no indication that explosive residues would be detected in any of the wells on Vieques. Explosive residues were

[1] It should be noted that only the explosive residue data were determined to be unusable; all the other data were acceptable.

sampled in water from fifteen wells (11 monitoring wells along EMA's western border, Well 2-3 in Martineau, and Well 3-7 in Proyecto Barracon, Navy Well 17 in the NASD, and Navy Well 14 in Camp Garcia) on Vieques, three of which are located in the same aquifer as the Sun Bay wells. Explosive residues were not detected in any of these wells.

28. **Comment:** *Two commentators found the circumstances surrounding EPA's September 1999 sampling of the Sun Bay wells to be mysterious. One commentator was baffled by the absence of any explanation in the PHA of why EPA suppressed its own results as unusable. Another commentator suggested that it was an extremely suspicious coincidence that the wells were closed (precluding further testing) shortly after these suppressed testing results. This commentator further asserts that the report of the September 1999 testing indicates that it underestimated explosive concentrations..*

Response: After EPA received and reviewed the complete data package from the contract laboratory, they determined that the explosive residue data were unusable because ten of the 15 samples tested for explosive residues did not meet the surrogate recovery specifications (e.g, the surrogate recoveries were below the 50% quality control criteria). In addition, an eleventh sample exceeded the allowable seven day holding time (EPA 1999c).

Because exceedances of the surrogate recovery specifications indicate an increased potential for low bias, EPA re-sampled for explosive residues in January 2000 (except the Sun Bay wells could not be re-sampled, see comment 27 above). This data were determined to be usable and no explosive residues were detected.

ATSDR does not know the rationale PRASA used for closing the Sun Bay wells.

29. **Comment:** *Two commentators expressed guarded skepticism that EPA exercised due diligence in its January 2000 attempts to re-sample the closed Sun Bay wells. One commentator noted that the well covers can be easily removed for purposes of either sampling the water or (in emergencies) consuming it. The other commentator noted that the PHA makes no statement of the level of effort with which EPA sought to gain access to the closed wells.*

Response: EPA explained that PRASA had planned on closing the Sun Bay wells prior to EPA's 1999 sampling. Under EPA's urging, PRASA did not close the wells until after EPA sampled. Neither agency expected that the Sun Bay wells would need to be re-sampled and when EPA returned in 2000, PRASA had already closed the wells (EPA Life Scientist; personal communication; October 9, 2001).

30. **Comment:** *One commentator insisted that both the 1978 and the September 1999 EPA sampling data indicate that the Esperanza groundwater supply is contaminated. The commentator cites a January 2000 statement made by EPA (in RCRA-02-2000-7301) that a human exposure pathway may exist via the emergency use of public wells.*

Response: Groundwater in the Esperanza valley was not sampled in 1978; therefore, this sampling event cannot indicate that the Esperanza groundwater supply is contaminated. In 1999, EPA sampled water from the three Sun Bay wells, which are located in the Esperanza valley aquifer (EPA 1999b). None of the chemicals were detected at a level of health concern.

Even if a human exposure pathway exists for drinking water from public wells, exposure does not always result in harmful health effects. The type and severity of health effects that occur in an individual from contact with a contaminant depend on the exposure concentration (how much) and the frequency and/or duration of exposure (how long). ATSDR accounts for these parameters, using high-end exposure level estimates as the basis when evaluating whether harmful health effects are possible. Through a comprehensive evaluation, ATSDR concludes that the levels of chemicals detected in the Sun Bay wells were too low to be of health concern and are therefore, safe to use in emergency situations.

Other Wells

31. **Comment:** *One commentator (EPA Region 2) states that neither the Peterson (Well 3-7) nor the Martineau well (Well 2-3) should be used for drinking water, even during emergencies. One of the commentator's concerns about these wells is that they are inadequately protected from surface runoff. Therefore, they risk contamination with bacteria, nitrites, and nitrates. EPA recommends that they be permanently closed. EPA inquires whether the PHA's "Well 2-3" is the same as EPA's "Martineau Well." If the two labels are one and the same, then EPA strongly disagrees with ATSDR's conclusion that the well is safe to drink from.*

Response: ATSDR focused the public health evaluation on the chemistry of the water in Peterson and Martineau wells, rather than on the wells' construction. Thank you for bringing the condition of the wells to our attention. ATSDR was unaware of EPA's recommendation to permanently close Peterson and Martineau wells. In light of EPA's concerns, ATSDR agrees that the construction of the wells may be inadequate to protect the water from future surface contamination.

Well 2-3 is USGS's well identification for the Martineau well.

32. **Comment:** *Two commentators disagreed with the PHA's conclusion that the elevated "nitrate+nitrite" levels in Well 3-7 are a result of runoff from agricultural pollution. The commentators denied that the PHA provided any real justification for this conclusion and believed that it was made arbitrarily. One commentator stated that 7,000 pounds of "drone fuel" (a mixture of nitric acid and mixed amine fuel #4) were disposed of near Building 422 of the NASD. The commentator stated that the PHA ignores the existence of drone fuel contamination, suggesting that a fuel spill, perhaps, is responsible for the contamination of Well 3-7.*

Response: ATSDR concluded that the elevated levels of nitrate plus nitrite in Well 3-7 are most likely the result of agricultural pollution because of the following reasons:

- Hydrogeologically, the groundwater from the LIA cannot migrate west into Well 3-7; therefore, the bombing at the LIA cannot be the source of the contamination *via* the groundwater pathway.

- Finding elevated levels of nitrate plus nitrite in Well 3-7 only and not in any of the other 14 wells that were sampled indicates a localized source of contamination (e.g., agriculture) rather than a source that would contaminate all the wells (e.g., aerial deposition from bombing at the LIA).

- Well 3-7 is located in the weathered bedrock on the eastern side of the residential area (see Figure 5). Any groundwater contaminated from a fuel spill in the NASD cannot migrate several miles east from the NASD into Well 3-7 because of the hydrogeology and topography of the island.

33. **Comment:** *One commentator stated the following:*

In September 1999, di(2-ethylhexyl)phthalate was found at levels above federal standards at the Peterson well. This chemical is commonly found in plastics but can also come from explosive compounds. EPA assumes the chemical was not actually present in the well but, rather, was introduced into the sample over course of lab handling. It is true that phthalates are often accidentally introduced into samples being tested for semi-volatile organics. However, if the sample was to be tested for phthalates themselves, the laboratory protocols would have specified strict precautions to avoid contamination.

In November 9, 1999, a report of EPA's Drinking Water Section recommended retesting to settle the question of whether the phthalates detected were present in the well or were introduced in the lab. However, no mention of this recommendation is made in EPA's January 20, 2000 summary report for the testing. A new, "reviewed" version of the original lab report was issued that eliminates all discussion of di(2-ethylhexyl) phthalate.

EPA made an arbitrary and unjustified decision to discard the testing results for this compound.

Response: EPA did not re-sample for di(2-ethylhexyl)phthalate because the low levels that were detected were not at a level of concern; therefore, EPA decided that di(2-ethylhexyl)phthalate did not need to be re-tested (EPA Life Scientist; personal communication; October 9, 2001).

34. **Comment:** *One commentator noticed that the PHA admits that water from small, unnamed alluvial deposits is being used. The commentator was concerned that no testing has been done to verify that these alluvial deposits are not harboring pockets of contamination.*

Response: In 1995, USGS identified 73 wells on Vieques; only one of which is located in the small, unnamed alluvial deposits (Cherry and Ramos 1995). It is a hand-dug well in Camp Garcia that is no longer in use; therefore, no one is drinking water from these unnamed alluvial deposits. As a reminder, ATSDR's PHAs are exposure (i.e., contact) driven. A release of a contaminant in the groundwater does not always result in harmful human exposure. If no one comes into contact with any *potential* contamination present, then there is no exposure and no health effects could occur.

35. **Comment:** *One commentator was dismayed that the PHA states that drinking water from the four B wells poses no public health hazard, given that none of these wells have been sampled for explosive compounds.*

Response: The B wells are located in the same aquifer and in close proximity to the Sun Bay wells. In May 1995, PRDOH sampled the water from the B wells for inorganics, metals, VOCs, SVOCs, pesticides, herbicides, and PCBs (PRDOH 1995b). Despite the lack of valid explosive residue data from the B wells, ATSDR can still make justifiable health decisions concerning the use of the wells in the event of an emergency. ATSDR does not expect explosive compounds to be detected at levels of health concern in the B wells for the same reasons we do not expect explosive compounds to be detected at levels of health concern in the Sun Bay wells (see comment 27).

Agree With Conclusions

36. **Comment:** *One commentator felt that the PHA accurately conveyed the fact that the Navy's activities do not hurt Vieques' drinking water supplies and/or groundwater.*

Response: Thank you for your acknowledgment.

37. Comment: *One commentator (PRDOH) indicated that, except as specifically noted elsewhere, the data cited in the PHA agrees with the data that the commentator has on record.*

    Response: Thank you for your acknowledgment.

38. **Comment:** *One commentator downplayed the notion that the Navy's military operations has had an adverse effect on the civilian population of Vieques. The commentator admitted that Camp Garcia periodically spilled fuels (e.g., "AV Gas, Mogas, JP. 4") but he did not believe that these spills took place at a magnitude sufficient to contaminate local groundwater. The commentator cautioned, however, that unexploded ordnance on the bombing/firing range is a serious hazard for protesters.*

    Response: ATSDR agrees with your concern about unexploded ordnance on the bombing/firing range and the safety of anyone entering the LIA. Fortunately, no accidents involving unexploded ordnance have been reported.

Disagree With Conclusions

39. **Comment:** *One commentator did not believe that ATSDR made a serious effort at fulfilling its legally mandated responsibility to protect public health.*

    Response: As discussed in the PHA, ATSDR's primary goal in the health assessment process is to put possible exposure to environmental contaminants into meaningful perspective for the public. In doing so, ATSDR strives to explain whether people are being exposed to harmful substances and, if so, whether the exposure may cause harm. For a more detailed discussion on ATSDR's mandate please see the "Foreword" of the PHA.

40. **Comment:** *One commentator found it impossible to accept the notion that the dust kicked up on the LIA could not have contaminated wells. If the wells were safe, the commentator reasoned, the residents of Vieques would not have been forbidden to use the public wells when their regular water supply failed for a week in mid-February, 2001.*

    Response: ATSDR was able to conclude whether drinking the public water or the groundwater was of health concern based on an examination of sampling data at the point of exposure. The sampling data do not indicate that bombing at the LIA has contaminated groundwater wells. To complement the drinking water supplies and groundwater pathway evaluation, ATSDR is addressing the transport of wind-blown dust generated from bombing at the LIA in a focused PHA pertaining to inhalation of air and dust.

41. **Comment:** *One commentator believed the PHA's conclusion is incorrect and that contaminants are migrating from the LIA to the populated center of the island. The commentator also criticized the PHA for failing to follow the scientific method.*

    Response: ATSDR based its conclusions on defendable hydrogeologic and topographic information that show that contaminants cannot migrate from the LIA to the residential section of the island through the groundwater pathway. ATSDR's assessment of potential contamination of groundwater and drinking water supplies in Vieques is based on information presented in environmental investigation documents by USGS and the Navy's contractor in addition to other sampling data by EPA, PRDOH, USGS, and the Navy's contractor. Collectively, the environmental information indicates that the extent of migration is limited because of the hydrogeology and topography of Vieques. In addition, the sampling data indicate that contamination has not migrated with groundwater beyond the Navy's border. Together, these factors provide compelling evidence that contamination has not reached the residential areas.

42. **Comment:** *One commentator states that she/he would like to be able to tell the citizens of Vieques that their water is uncontaminated, but unfortunately the available data support the opposite conclusion.*

    Response: ATSDR disagrees that the available data support a conclusion opposite to the ones we established in the PHA.

43. **Comment:** *One commentator accuses ATSDR of purposefully failing to draw obvious logical connections between the presence of certain contaminants in well water and their presence on Navy land. As evidence that there is some transport of contaminants from eastern Vieques to the Resolucion aquifer, the commentator reminds ATSDR that the PHA noted the presence of trace quantities of benzene and toluene in Navy Well 17 (in the Resolucion aquifer). Even if these chemicals are present only at small levels, the commentator concluded, they still provide evidence that the LIA is not completely chemically separated from the rest of Vieques.*

    Response: Benzene and toluene were detected in a former supply well in the Resolucion aquifer (Navy Well 17); however, neither was detected in the other 14 wells which were also tested for VOCs. This lack of detection elsewhere indicates that a localized source (perhaps a fuel spill) contaminated this well rather than a source that would contaminate all the wells.

Incomplete Evaluation

44. **Comment:** *Three commentators were outraged that ATSDR felt confident in offering paternalistic reassurances about the safety of Vieques' drinking water while simultaneously issuing disclaimers that in some respects their data might be incomplete. "If adequate scientific evidence was not available," wrote one commentator, "the conclusions should have been postponed." It seemed to one commentator as if ATSDR had started with the presumption that the community's health was not at risk until proven otherwise. This perceived stance came across as an insulting bias—as, perhaps, a sign of deliberate scorn for the people of Vieques.*

Response: When evaluating public health hazards, ATSDR prefers to use as much information as possible when assessing environmental exposures. However, sometimes data are limited, particularly for past exposure scenarios. With limited data, ATSDR uses the available information about site conditions and our best professional judgement to draw conclusions and make appropriate recommendations. Following this approach, we had sufficient information to address the central question of whether residents of Vieques are being exposed to harmful levels of contaminants in their drinking water and groundwater supplies.

ATSDR wants to reassure the reader that we based our public health decisions on the best available scientific evidence, and with great consideration to the concerns voiced by the people of Vieques. ATSDR's primary goal is to identify possible site-specific exposures to environmental contaminants and determine their probable implication for the Vieques' community. Because our public health assessments are exposure driven, we first identify whether residents of the island have contacted or could come into contact with harmful substances. Part of the challenge we face in doing this is explaining to the community that while contaminants may exist in the environment, exposures are only possible if people actually come in contact with contaminated media. If you have specific concerns that prompted these comments, ATSDR is available to further explain the basis of its public health conclusions.

45. **Comment:** *One commentator acknowledged that the PHA was completed under time pressure and that it is tightly focused. Nevertheless, the commentator felt that the PHA fell short of its goals. It inspires little confidence in the reader when it states the obvious: that water piped in from Puerto Rico is safe to drink. When confronted with potentially contaminated water, ATSDR either:*

a) says it is safe without adequate justification;
b) says it is polluted but assumes, without justification, that its pollution is unrelated to explosives (Well 3-7); or

c) ignores the question of whether or not it is safe because of a lack of data (rainfall collection systems).

Response: The public water supply system was evaluated by ATSDR because there were concerns that the bombing at the LIA could potentially affect this system. In 1978, an environmental consultant hired by the Government of Puerto Rico demonstrated that air was being sucked into the public water storage tanks (EPA 1999a). In addition, EPA sampled potable water supply and distribution tanks in 1999 because various parties raised concerns that explosive residuals were potentially contaminating the water supply (EPA 1999b). Therefore, to dismiss these concerns without a full evaluation because it seems obvious that water piped in from Puerto Rico is safe to drink, would not have met ATSDR's goal of addressing the environmental health concerns of the residents.

ATSDR strongly affirms that adequate justification for the conclusions we draw are presented in the PHA.

Specific issues in this comment are addressed throughout the responses to comments.

46. **Comment:** *One commentator said that the PHA needs to distinguish which conclusions can be drawn and, more importantly, which conclusions cannot be drawn from the information presented. Right now, people might be misled into concluding, from reading the PHA, that their water supplies are not affected by explosive-related contamination. Considering that the Sun Bay wells have not been tested for explosives, this is an unjustified conclusion.*

Response: Based upon a thorough evaluation of the available sampling data, there is no evidence that water supplies are being affected by explosive-related contamination. In addition, the hydrogeologic and topographic information indicates that contaminants cannot migrate from the LIA to the residential section of the island through the groundwater pathway.

Despite the lack of valid explosive residue data for the Sun Bay wells, ATSDR can make justifiable health decisions concerning the use of the Sun Bay wells in the event of an emergency. ATSDR does not expect explosive compounds to be detected at levels of health concern in the Sun Bay wells for the reasons outlined in the response to comment 27.

47. **Comment:** *One commentator criticized the PHA for extrapolating the results of tested wells to untested wells. The commentator stated that the PHA was based on only a limited sample of the wells on Vieques (only 18 out of 73 were tested). Furthermore, there is no reason to believe that those 18 are representative of the rest. A 1991 USGS survey stated*

that 4 wells on Vieques were then being used for drinking water. EPA analyzed only one of these. How can ATSDR generalize from one to the other three?

Response: It is true that 73 wells have been identified on Vieques (Cherry and Ramos 1995). However, according to the report, only seven of these wells were in use: one was used agriculturally to water livestock (Well 2-2), four were used for drinking water and other domestic purposes (Wells 3-4, 3-5, 3-7, and 10-2), and two were used to supply public water to Camp Garcia personnel (Wells 11-14 and 11-17). The remaining wells were listed as not in use. Therefore, even though 73 wells may exist, no one is drinking water from the majority of them and, consequently, are not being exposed to any potential contamination.

ATSDR focuses our public health evaluation on contamination of private wells that supply drinking water to the residents of Vieques. Therefore, the discussion in the PHA is centered on Wells 3-4, 3-5, 3-7, and 10-2. Of the four wells, Well 3-7 has been sampled and conclusions were drawn based upon the data.

Wells 3-4, 3-5, and 10-2 are located in weathered bedrock to the west of the EMA. The only way for any contamination from the LIA to reach this area of the island is through aerial deposition; not groundwater flow. A PHA will be released to deal specifically with the air pathway; however, ATSDR based some of the conclusions in this PHA on the basic principle that aerial deposition will not have significant spatial variations at locations approximately 7-10 miles from the source (i.e., the amount of material falling from the air is expected to be relatively consistent across the residential area).

To evaluate the likelihood that Wells 3-4, 3-5, and 10-2 are being contaminated by activities at the LIA, we looked at other wells located in the weathered bedrock. Nine monitoring wells, located in the weathered bedrock along EMA's western boundary, were sampled for explosives. Wells 2-3 and 3-7, also located in the weathered bedrock, were sampled for VOCs, SVOCs, inorganics, metals, and explosives. Of all of these chemicals sampled from these 11 wells, only nitrate plus nitrite was detected at a hazardous level in Well 3-7.

Since we attribute the nitrate plus nitrite levels in Well 3-7 to local agricultural sources rather than bombing at the LIA (because of the reasons listed the response to comment 27) we would not automatically expect these levels to be in all the wells. Local sources might potentially contaminate any well. Therefore, ATSDR previously recommended that, when shallow drinking water wells are found in use, PRDOH or PREQB should sample the wells to assure that the water is safe to drink.

Geology and Hydrogeology

48. **Comment:** *One commentator remarked that the PHA claims that the Esperanza aquifer is not of high quality because it is contaminated with metals and total dissolved solids. While the PHA attributes this fact to circumstances of natural geography, the commentator attributes it to Naval activities on Vieques.*

    Response: ATSDR believes that metals and total dissolved solids found in the groundwater are attributable to the natural geology and geography of Vieques. The groundwater evaluation conclusively indicates that groundwater at the LIA cannot travel west (upgradient and past a geologic barrier) into the residential area. Of more importance to ATSDR, and users of the drinking water wells, is that while metals and total dissolved solids were detected in the groundwater, the concentrations that are present were not at levels of health concern (except nitrate plus nitrite in Well 3-7).

49. **Comment:** *One commentator cited the fact that ATSDR omitted discussion of a CH2MHILL report that presents pollution in western Vieques in the PHA as evidence that ATSDR personnel lack the necessary expertise to competently evaluate public health at Vieques..*

    Response: ATSDR reviewed evidence of groundwater contamination in the former NASD area (Navy 2000). Although information presented for that area does not fully characterize the extent of this contamination, there is not now and has not been in the past a potential pathway of human exposure to those contaminants.

50. **Comment:** *One commentator asks ATSDR to incorporate into the PHA a discussion of how pumping wells may disrupt the normal flow of groundwater. The commentator suggests that the fact that salt water has intruded into heavily pumped freshwater aquifers is evidence that wells may significantly alter the natural movement of groundwater. Furthermore, the commentator argues that it is inadequate to simply study the groundwater patterns that exist at present. One must also study the groundwater patterns that existed in the past, when groundwater pumping was more prevalent.*

    Response: Pumping groundwater from wells does influence the flow of groundwater in the near well area. A production well has a radius of influence, within which groundwater levels are drawn down due to pumping. The radius of influence is a function of the well's design, operation, and surrounding aquifer parameters and can range from a few feet to more than a mile. Perhaps more importantly, when wells pumping from an aquifer draw out more water than is recharged by rainfall and other sources, the level of the whole aquifer drops.

The fact that saltwater intruded into heavily pumped freshwater aquifers is evidence of aquifer drawdown, and is independent of the groundwater flow direction. Because of excess pumpage, the hydraulic head of the freshwater over the saltwater was reduced, allowing the freshwater/saltwater interface to move inland (Torres-Gonzalez 1989).

The lack of comprehensive historical groundwater elevation data makes discussion of past groundwater flow direction speculative, especially considering how important secondary porosity (water contained in bedrock fractures and joints, which is difficult to model or characterize without exhaustive sets of data) is to the groundwater regime on Vieques. The most common way to characterize past groundwater movement is through numerical modeling. The USGS created such a model in 1989 (Torres-Gonzalez 1989). However, they were only able to create a steady-state model (i.e., one that pertained to the 1989 data set). Calibrating a transient model (i.e., one that would extrapolate groundwater levels over time) was precluded by limited data (Torres-Gonzalez 1989).

Beyond the zone of the well's influence, the regional patterns of groundwater flow are not altered. Thus, the pumping rate and history of the large public wells located in aquifers isolated from the sources of contamination are not factors that determine past pathways of contaminant migration.

51. **Comment:** *One commentator disputes the PHA's conclusion that a geological barrier prevents water movement between the groundwater near the LIA and groundwater in the Esperanza alluvial valley. The commentator cites CH2MHILL and Baker's 1999 study, which shows that water moves southwest (not south) from the region that ATSDR considers to be a barrier, potentially contaminating the Sun Bay wells west of Puerto Ferro.*

    Response: CH2MHILL and Baker's study does show south and southwest moving groundwater flow originating from the southwest side of the groundwater barrier. Groundwater flow is also shown as heading northeast and east from the northeast side of the groundwater barrier. However, the LIA is over six miles east of this groundwater divide. As such, groundwater originating to the east of the groundwater divide will not flow upgradient to the west and; therefore, cannot flow towards any wells west of the divide (CH2MHILL and Baker 1999). Groundwater in unconfined aquifers does not flow uphill.

52. **Comment:** *One commentator notes that military debris at LIA is never removed from the site. Rather, it is simply bombed over or buried, creating a potential for groundwater contamination.*

Response: Despite any source of contamination, groundwater at the LIA is hydrogeologically isolated from aquifers in the residential area of the island and therefore, cannot affect the quality of the groundwater in the residential area (see also response to comment 51).

53. **Comment:** *One commentator disputes the adequacy of CH2MHILL and Baker's hydrogeology study, on a variety of grounds:*

- *CH2MHILL and Baker gives no justification for their choice of the western boundary of the Eastern Maneuver Area as its focus of groundwater sampling.*

Response: CH2MHILL and Baker explain their choice of the western boundary of the EMA as its focus of groundwater sampling in Section 1.1 "Purpose and Objectives of the Field Investigations" and Section 3.2.1 "Groundwater Investigation – Investigation Rationale" (CH2MHILL and Baker 1999). The purpose was to determine whether explosive compounds were present and if they were moving off site from on-site sources of contamination. In other words, they were looking for contamination flowing over the boundary. Therefore, they needed to test for contaminants at the boundary and determine the flow direction at the boundary.

- *Soil samples were taken only of the first 6 inches of soil, well above the level of any aquifers. Water samples were only taken from the bottom of aquifers, well below the level at which contamination would likely be manifested. Instead of conducting such limited sampling, CH2MHILL and Baker should have systematically sampled water and soil, at different depths but at a geographic single location.*

Response: According to section 3.1.1 "Soils Investigation – Investigation Rationale," the goal of the surface soil investigation was to determine whether or not surface water runoff and transport through air dispersion was carrying contaminants off site (CH2MHILL and Baker 1999). Drilling of boreholes, and collecting and testing subsurface soil samples would not have addressed this goal. If surface soil has not been contaminated, then soil beneath it could not have been contaminated from a surface source.

Wells installed in the bedrock were drilled to the depth at which water was first encountered. During well development at least three of the wells were bailed until dry. When groundwater elevations in some of these wells were later measured, they were much higher. However, when six of the wells were measured, the depth to water was within 15 feet of the top of the well screen. The sources of water for the bedrock wells were fractures and joints in the bedrock. Since these wells were installed in such a low-flow formation, all the water in the wells originated from a water bearing fracture. As such, the samples are not missing potentially contaminated water at a higher elevation. Additionally, two of the wells (NW-8 and RCRA-4) were specifically designed to allow sampling of the Esperanza Aquifer, where the groundwater elevation in both of the wells was measured within three feet of the top of the screen (CH2MHILL and Baker 1999).

- *Soil sampling was conducted in regions where there was no runoff from rain. It is unknown how the results from runoff areas may differ from these results.*

Response: Soil sampling was conducted near surface water runoff drains and monitoring wells (CH2MHILL and Baker 1999). These locations address two concerns—the presence of contaminants in surface water runoff and the connection of surface water infiltration to groundwater.

- *The operational wells constructed by PRASA had not been operating for a period exceeding 48 hours before they were tested by CH2MHILL and Baker. This lack of pre-operation means that the test results do not reflect the overall quality of the groundwater feeding each well but rather the quality of the groundwater which has colleted in immediate proximity to the well.*

Response: CH2MHILL and Baker did not collect any samples from PRASA wells (CH2MHILL and Baker 1999). Prior to collecting groundwater samples from its monitoring wells, CH2MHILL and Baker purged each well of at least three well volumes (except well NW-1, which had a low capacity, allowing only one well volume to be purged) to make certain that the water samples collected were representative of formation water, not stagnant water that had collected in the well casing.

- *CH2MHILL and Baker furnishes no evidence to assure residents that it has been comprehensive in its identification of all the different aquifers which may exist on Vieques.*

Response: CH2MHILL and Baker's approach of installing wells and testing along the EMA boundary addresses the question of whether or not groundwater contamination is migrating off site from an on-site source. CH2MHILL and Baker did not set out to identify all of the different aquifers on Vieques. The goal of the CH2MHILL and Baker investigation was to find out whether or not explosive-related chemical compounds were migrating from the Navy property off site towards the homes and wells of the residents of Vieques.

54. **Comment:** *One commentator argues that due to topologically variable patterns of dust fallout, rainfall, and soil permeability, contaminated dusts could generate highly localized pockets of chemical contamination. The commentator argues that this is a*

particularly serious problem because there are many small, discontinuous "micro-aquifers" on Vieques. Thus, the commentator implies, the chemical contamination of Vieques' groundwater may be so heterogenous that existing data are inadequate to support general statements about its safety.

Response: While very complex scenarios cannot be completely ruled out, the public health assessment process protects against a wide range of potential threats using all the available information. Should new information become available that identifies locations of potential "micro-aquifer" contamination, the effect of that information on the current conclusions of the public health assessment can be evaluated. Additionally, the public health assessment for the air pathway will address the potential pathways associated with airborne dust.

Stop Bombing

55. **Comment:** *One commentator recommended that military exercises at Vieques be suspended pending a full and accurate health effects evaluation. The commentator reminded ATSDR that it is better to err on the side of caution than to err on the side of mediocrity and indifference.*

Response: During visits to Vieques and through a comprehensive evaluation of drinking water supplies and the groundwater pathway, ATSDR found no evidence of public health threats causing significant harm to the public's health that would require an immediate suspension of the bombing activities. If an acutely toxic situation were identified, ATSDR would have requested actions, including an immediate halt to the bombing, to protect public health. ATSDR is further evaluating other potential pathways of exposure (e.g., soil and air) through focused PHAs. If a harmful situation is identified in any of the pathways, ATSDR will request that the necessary steps be taken to protect public health.

Past Data Issues

56. **Comment:** *One commentator said that ATSDR overreaches itself when it makes claims to have evaluated the past impacts of Naval activities on public health. In fact, it has only gathered data about a portion of the period during which Navy has been at Vieques. Only one study, conducted in 1978, is available to represent conditions on Vieques prior to 1995. The commentator reminds ATSDR that the Navy took over Vieques property in 1941, targets were established in 1960, and Naval training exercises began in 1971. The commentator also reminds ATSDR that the 1978 study did find explosives in a drinking water well. Current data, the commentator argues, are insufficient to draw conclusions about the extent of past exposures. The current PHA cannot justifiably conclude that there have not been past exposures to explosive compounds in drinking water.*

Response: Prior to the late 1970s, little if any environmental monitoring occurred, owing largely to the absence of federal, state, or local environmental requirements. This problem is not specific to Vieques, but is a common concern at many sites throughout the world. One of the challenges we face is to evaluate public health hazards that may have occurred in the past, given the absence of adequate environmental monitoring. Where no historical data exist, we review available environmental and contaminant fate data and make assumptions about past exposure using our best professional judgement to draw conclusions regarding the likelihood of potential exposure to harmful levels of contaminants.

ATSDR has stated in the document that very low levels of cyclotrimethylene trinitramine (RDX), methyl-2,4,6-trinitrophenylnitramine (tetryl), ammonia, and nitrate plus nitrite may have been present in drinking water samples taken by the Navy in 1978. The validity and utility of the data are uncertain because of the small numbers of samples collected and the description of the location or media represented by the samples. Regardless, the concentrations of explosive compounds reported in drinking water in the past were well below levels considered harmful to human health and any potential past exposure to these compounds would not have posed a public health hazard. Although activities occurred at the LIA prior to 1978, ATSDR's review of historical activities did not find indications that conditions would have been such that a greater potential for contamination of the groundwater existed at that time.

1978 Data

57. **Comment:** *One commentator complained that ATSDR only provided details about four of the samples taken in the 1978 Naval Surface Weapons Center Water Sampling Data* (Hoffsommer and Glover 1978; Lai 1978), *presumably on grounds that only these four samples represent drinking water. The commentator stated that ATSDR should furnish all the data because they will all be useful in characterizing the effects of the LIA activities on the environment.*

Response: Regardless of the presence or extent of contamination detected in environmental samples from the site, exposures are only possible if people drink or otherwise come in contact with the groundwater. That is why whenever possible, ATSDR uses data collected directly from drinking water sources, rather than data from bomb craters or lagoons not being used to supply drinking water. As we discuss in the PHA, no one uses groundwater drawn from beneath or immediately near the LIA. ATSDR believes that the contaminant levels detected in the four drinking water samples discussed in the PHA more accurately represent the water component supplied to and used by Vieques residents.

58. **Comment:** *Two commentators asserted that the 1978 Navy study found that the concentrations of man-made explosive compounds (e.g., RDX) present in drinking water sources near Isabel Segunda and Esperanza were essentially the same as those found in puddles on LIA. This finding undermines the PHA's thesis that contamination cannot migrate from the LIA to residential area of the island. The commentator emphasizes that the overall magnitude of these concentrations is not the issue of importance. The issue of importance is that these data provide evidence of transport mechanisms linking contamination at the LIA contamination elsewhere on Vieques.*

    Response: Finding RDX in a public drinking water supply tank does not undermine our conclusion that contamination cannot migrate through the groundwater pathway from the LIA into the residential section. First, the public water is supplied from a river on the mainland of Puerto Rico. Second, a careful analysis of the hydrogeology and topography of Vieques conclusively shows that groundwater at the LIA cannot travel upgradient, past the groundwater divide, and into residential wells to the west. Therefore, the RDX detected[2] in the Isabel Segunda and Esperanza tanks did not migrate there through the groundwater pathway. ATSDR is addressing the issue of contaminants traveling from the LIA into the residential section of Vieques through the air in another focused PHA

    Contrary to the commentator's opinion that the magnitude of the concentration is not the important issue, ATSDR asserts that the chemical's concentration is a highly important factor in the public health assessment process. Looking at exposure by itself will not address the issue of whether that exposure will result in harmful health effects. The type and severity of health effects that occur in an individual from contact with a contaminant depend on the exposure concentration, the frequency and duration of exposure, and how the contaminant is absorbed, distributed, metabolized, and excreted.

59. **Comment:** *One commentator found it outrageous that ATSDR suggested that the nitrate plus nitrite levels in water samples from bomb craters could have come from agricultural sources. The commentator suggested that unless ATSDR furnishes convincing evidence for a counter-theory, it should presume the more obvious conclusion that these levels are the result of explosions.*

    Response: ATSDR apologizes for the lack of clarity related to this comment. The paragraph has been revised in the PHA to more accurately state the intended focus on the drinking water samples. While it is possible that nitrate plus nitrite that is detected in

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[2]There is some uncertainty that RDX and tetryl were truly detected in the samples. The authors of the study note that "a completely positive identification was not possible due to the extremely low concentrations found" (Hoffsommer and Glover 1978; Lai 1978). ATSDR discusses the limitation of the study in detail in Appendix E of the PHA.

water from a crater on a bombing range may indicate a source of explosives or residual compounds, nitrate may be present in the environment from a wide variety of sources and mechanisms. It is true that NO_2 gas is one emission resulting from detonation of high explosives. It is also true that NO_2 gas is a major component of the atmosphere. The NO_2 gas in the atmosphere, regardless of its source, can be converted through natural processes to nitrate. This is just one of many explanations available for the presence of nitrate in pond water. Thus, measured levels of nitrate (or nitrite) cannot be considered conclusive evidence of the presence of explosives or explosive, especially in the residential area. Nitrate plus nitrite can also indicate other sources of contamination such as agricultural fertilizers.

60. **Comment:** *One commentator denied the PHA's claim that the only groundwater samples in the Esperanza aquifer available to characterize the potential for explosives contamination are the Navy wells that were sampled in 1999. The commentator claimed that the Esperanza aquifer data from both the 1978 and the 1999 EPA studies provide evidence of explosive contamination. In 1978, for example, small levels of RDX were found in the Esperanza groundwater supply and there has been no subsequent retesting to confirm or refute these findings.*

Response: The water sample taken from Esperanza in 1978 was from a public water supply tank, not of the Esperanza aquifer (Hoffsommer and Glover 1978; Lai 1978); therefore, this sample cannot provide evidence of explosive contamination in the groundwater. In 1999, EPA sampled for explosives in wells located in the Esperanza aquifer, however, the data were determined to be unusable (EPA 1999b). This does not imply that there was evidence of explosive contamination; no conclusions can be drawn from unusable data. There are three wells (a former supply well in Camp Garcia and two monitoring wells) located in the Esperanza aquifer that have recently been sampled for explosive residues and have not shown any evidence of explosive contamination (Baker 1999; CH2MHILL and Baker 1999).

Depleted Uranium

61. **Comment:** *Two commentators were concerned about the possibility of air pollution resulting from the use of depleted uranium (DU) ammunition at the LIA. One commentator hypothesized that radioactive bullets lying on the ground might be pulverized into dust by subsequent explosions. Another commentator noted that vapors are created when a bullet hits its target.*

Response: As explained in the PHA, two U.S. Marine Corps aircrafts fired 263 rounds of ammunition armed with DU penetrator projectiles on the LIA in February 1999. The Nuclear Regulatory Commission (NRC) conducted an environmental survey on Vieques in June 2000 to address the community's concern that DU could be transported from the LIA to the residential area (NRC 2000a, 2000b). The inspectors performed independent direct measurements of radiation levels and collected and analyzed environmental samples both inside and outside the LIA. NRC concluded that DU from the firing of DU penetrators into the LIA had not spread to the environment outside the LIA. In addition, the Navy has committed to the recovery of all detectable DU rounds from the LIA and has recovered 116 equivalent units as of September 2001.

The possibility that some DU would be volatile is a legitimate concern. However, DU, like uranium, is extremely dense and would rapidly settle to the ground. If the material were to migrate the 7.9 miles from the LIA to the residential areas of the island, the concentration expected would be well below levels of uranium known to cause adverse health effects. Also, if the DU remaining in the impact area were to be impacted by other inert weapons, there would be no significant DU vapors produced as there is no excessive heat generated. The amount of DU injected into the atmosphere by those impacts would also settle rapidly.

62. **Comment:** *One commentator complained that the NRC report on DU use contained significant errors and omissions. The commentator:*

- *Challenged NRC to justify its decision to limit its sampling to soil 6 inches or less below the surface. The commentator stated that there is no reason for believing that there are not DU bullets buried deeper in the soil.*

Response: People can receive a dose of environmental DU through internal and external exposures. Internal exposures can occur from inhalation of particles, direct ingestion of soil, ingestion of produce that contains DU from the soil, and drinking water containing DU. External exposure is usually very small because DU is less radioactive than natural uranium. The radiation from DU in soil through many of the internal and external routes is important only for DU near the surface; therefore, when addressing health concerns it is appropriate to measure the DU near the surface.

There are two methods of DU entering the body that may require knowledge of DU below the surface: (1) plant uptake of DU through the roots and (2) DU in the groundwater. The uptake of DU by plants is partially accounted for by the surface concentration. In addition, NRC investigated plant uptake by collecting plant samples, thereby making deeper soil sampling unnecessary. DU in groundwater beneath the LIA is not of health concern because no one is drinking the groundwater beneath the LIA and the groundwater is hydrogeologically isolated from the residential section of Vieques. Therefore, collecting surface soil samples is adequate for addressing health concerns.

- *Regretted NRC's sampling method, which apparently involved pooling five 1-kilogram samples from a single sampling area. The commentator suggested that actual levels of radioactivity in a sampling area may be quite heterogenous and that the act of pooling samples may obscure detection of localized areas of significant radioactivity.*

Response: NRC sampled to characterize the DU concentration distributions and estimate dose from the DU concentrations. Dose estimates are made from average concentrations per unit area and the concentration distribution. Pooling samples to obtain the average concentration per unit area is an acceptable and recommended process, following guidance in the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM). The pooling of samples gives an estimate of the average concentration for the pooled samples, but also allows estimating the upper bound for a single sample. If it is assumed that the entire DU came from a single sample then the upper bound concentration for the samples is 5 times the average. Dose is estimated from the average contribution from the area represented by the samples, so the estimated dose is the same regardless of the DU distribution within the area.

- *Argued that the laboratory commissioned by NRC to detect DU used the wrong analytical methods. The commentator contended that the laboratory used alpha and gamma spectroscopy to when it should have used a technique known as ICP-MS.*

Response: Most laboratories can detect all uranium isotopes down to about 0.02 pCi per sample. This is usually sufficient to detect U-235 at the average natural background level. However, depleted uranium has much less U-235, so the accuracy of detection of additional U-235 would be poor. The interest is in concentrations of DU much higher than background levels. In depleted uranium the U-234 activity is about 10 times higher than U-235 activity. Therefore, alpha spectrometry is an adequate method to measure DU based on U-234 when U-235 is not well detected. ICP-MS can be used to differentiate the difference in the masses of the uranium. However, since we know DU was used, differential detection of the uranium isotopes is not required.

- *Stated that the NRC report lacks a section describing chain-of-custody or quality control procedures.*

Response: The cover letter for data transmittal from Dale Condra of ORISE to Jay Henson of NRC (August 24, 2000) states that all Quality Control procedures were followed for the analyses. The ORISE Quality Control requires completion of chain-of-custody. Since all Quality Control was completed at ORISE, by inference the chain-of-custody documentation was complete. The commentator should request chain-of-custody and sampling quality control from the NRC.

63. **Comment:** *One commentator denied that NRC report's hydrological observations were adequate to support the conclusions that ATSDR drew from them. The commentator stated that NRC presents no sampling data for groundwater or drinking water—only data for sediments and surface water. Furthermore, the commentator stated that none of the sediment and surface water sampling conducted took place at the LIA itself.*

    Response: The NRC report establishes that DU has not migrated to the residential area through the air (NRC 2000a, 2000b). In addition, DU was not detected in the environment, except in the soil immediately surrounding the DU penetrator. This is not surprising since the density of DU is such that it is not expected to carry very far and will; therefore, settle close to its impact area. DU in the soil at the LIA could migrate into the groundwater at the LIA. However, groundwater at the LIA is isolated from the groundwater in the residential area; therefore, any potential DU contamination present could not affect the groundwater or drinking water on Vieques.

64. **Comment:** *One commentator suggested that ATSDR has been credulous in accepting that the only DU contamination at LIA is that which Navy has acknowledged was released in 1999. The commentator was puzzled that ATSDR does not take a more skeptical stance towards information provided by the Navy, at least until obtaining independent verification. The commentator asserted that the Navy erroneously supplied an entire aircraft carrier with DU ammunition and that DU contamination may therefore be greater than the Navy currently admits. Furthermore, the commentator claimed that Vieques residents are capable of distinguishing those bullet holes which are made by DU bullets and that residents started finding these special bullet holes in the LIA before 1999. The commentator denied that samples were taken from <u>all</u> of the "civil disobedience camps" present on the LIA.*

    Response: NRC has regulatory authority over the use of DU on the LIA. The incident was reported to the NRC by the Navy and was investigated by the NRC. ATSDR reviewed the evaluations carried out by the NRC and believes that appropriate sampling methodology and analyses were carried out. If more widespread use of DU was carried out, evidence of it would have been discovered through the sampling efforts of the NRC.

Non-technical Comments

65. **Comment:** *Two commentators found the PHA to be well-written and informative. They offer their thanks to ATSDR for its efforts.*

Response: Thank you for your acknowledgment.

66. **Comment:** *Five commentators disparaged ATSDR and its PHA on a variety of grounds (unscientific, biased, inadequate, etc.). One commentator complained that the PHA was put together too hastily and did not involve any original research. Three commentators questioned whether ATSDR is capable of conducting an unbiased investigation of public health at Vieques. Two commentators expressed the opinion that ATSDR operates as a puppet of the Navy.*

    Response: ATSDR is an independent public health agency in the Department of Health and Human Services. In evaluating potential public health hazards, ATSDR thoroughly reviews available environmental data. ATSDR reviews relevant material from a variety of sources for the exposure pathway of concern. For the drinking water supplies and groundwater evaluation, ATSDR based its conclusions and recommendations on available environmental data and exposure information provided by the Navy, EPA, PRDOH, and USGS. For a more detailed discussion on our process, please refer to the "Foreword "of our PHA. You may also review the Vieques documents cited in the "Reference" section of this PHA.

67. **Comment:** *One commentator was concerned that ATSDR might be conducting an epidemiological study of cancer risk in Vieques. The commentator feared that ATSDR would mishandle such a study.*

    Response: Since the beginning of ATSDR's involvement on Vieques, many people have expressed serious concerns about cancer, citing reports that cancer rates on the island are significantly higher than on the mainland of Puerto Rico. In order to carry out a credible epidemiological study that might address the cause of a disease or a group of diseases, a clearly exposed group of people must be identified and compared with a non-exposed group of similar characteristics. Complete evaluation of exposure pathways is currently ongoing. The design of such an epidemiological study could be considered only after identification of exposed populations.

    The Puerto Rico Central Cancer Registry is being updated by PRDOH. Data for more recent years are not yet complete. The National Program of Cancer Registry standards suggest that data be at least 90% complete before statistics on new cases and deaths are published. A team of highly qualified scientists and physicians from The Centers for Disease Control and Prevention (CDC) is providing technical assistance to the Puerto Rico Central Cancer Registry staff to help achieve national standards.

68. **Comment:** *One commentator stated that ATSDR has a bad reputation among residents of Vieques. The commentator said that the community of Vieques has rejected ATSDR's conclusions and refused to participate in ATSDR's March 14, 2001 meeting.*

Response: At the outset, and as an integral part of the continuing public health process, ATSDR seeks to foster open dialogue with the community about health concerns. ATSDR has visited Vieques on many occasions and has had useful discussions with small groups of residents, political leaders, and health care providers. ATSDR took note of their health concerns. Although attendance at the March 14, 2001, meeting was small, the goal was to have ATSDR staff available in person to discuss with Vieques residents the findings of the evaluation of groundwater and drinking water. Local residents who have site-related concerns or who have questions about ATSDR's evaluations still have the opportunity to talk to staff directly and confidentially by calling the agency's toll free number, 1-888-42ATSDR.

69. **Comment:** *Two commentators complained that many of the documents upon which ATSDR's conclusions were founded were unavailable for them to review. They indicated that ATSDR has refused to directly furnish these documents and has referred them to the Navy instead. The commentators noted that some of the documents they seek can only be obtained from the Navy via a Freedom of Information Act (FOIA) request.*

Response: Many of the documents cited in the PHA are available to the public in document repositories on Vieques. The Freedom of Information Act is an appropriate mechanism to obtain documents from the federal agency that was the author of the document.

70. **Comment:** *Two commentators deplored the effects of the Navy's activities on the island of Vieques. One commentator noted that the Cerro Matias Impact Area looks hellish. Another commentator stated that Vieques is in the middle of an environmental crisis that requires immediate action. The commentator insisted that the Navy should immediately cease using land on Vieques.*

Response: Certainly the activities at a bombing range would impact the immediate environment. The evaluation of groundwater and drinking water by ATSDR focused on the potential impact on human health. Part of our challenge is explaining that while contaminants may exist in the environment or the character of the landscape may be changed from bombing practices, exposures are only possible if people come in contact with contaminants. Even though the LIA has been environmentally impacted by bombing target practices—ATSDR found no evidence in this drinking water evaluation that human exposures are occurring, or have occurred in the past, at levels of health concern.

71. **Comment:** *One commentator did not expect ATSDR to find evidence that the Navy is currently causing environment contamination. The commentator imagined that the Navy is now operating on its "best behavior" in response to the monitoring activities that are currently going on.*

    Response: Improved conditions are largely a result of environmental legislation that has been enacted since the late 1970s. Prior to that time, little if any environmental monitoring occurred, owing largely to the absence of federal and local environmental requirements. The new laws, aimed at protecting land and public health, now provide guidance for identifying and cleaning up chemicals and hazardous substances released in the environment.

72. **Comment:** *Two commentators made sociological statements about the island of Vieques. One of these commentators felt that the people of Vieques have been neglected, in general, by the government of San Juan. The commentator viewed the construction of a piped water supply from the mainland as an exception to this larger pattern of neglect. The other commentator was not surprised that the people of Vieques are suspicious of the PHA because they have been an oppressed people for so long and they have only recently found their voice.*

    Response: The comments are noted.

73. **Comment:** *One commentator applauds ATSDR's efforts to investigate additional exposure pathways, but doubts that any of these other pathways will be identified as potentially harmful.*

    Response: Only a comprehensive evaluation of human exposure to contamination can adequately determine whether other pathways are potentially harmful. ATSDR will continue to identify and evaluate exposure pathways by considering how people might come into contact with areas of potential contamination, whether contamination is present, and whether the amount of contamination is sufficient to affect people's health.

74. **Comment:** *One commentator finds the PHA uninteresting because it focuses on an exposure pathway—consumption of water imported from mainland Puerto Rico—that the commentator would not have expected to be a significant public health risk.*

    Response: ATSDR realizes that the water from the public water supply system originates from the mainland of Puerto Rico, is regulated by PREQB and PRDOH under EPA's Safe Drinking Water Act to be acceptable for human consumption, and therefore, is not likely to be a significant public health risk. However, this PHA not only addresses consumption of water from the mainland of Puerto Rico, but also consumption of water from public and private groundwater wells on Vieques.